Office for Nuclear Regulation

ONR Assessment Report

Generic Design Assessment of the BWRX-300 – Step 2 Assessment - External Hazards

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Executive summary

In December 2024, the Office for Nuclear Regulation (ONR), together with the Environment Agency and Natural Resources Wales, began Step 2 of the Generic Design Assessment (GDA) of the BWRX-300 design on behalf of GE Vernova Hitachi Nuclear Energy International LLC (UK Branch), the Requesting Party (RP).

This report presents the outcomes of my external hazards assessment of the BWRX-300 design as part of Step 2 of the ONR GDA. This assessment is based upon the information presented in the RP's safety, security, safeguards and environment cases (SSSE), the associated revision 3 of the Design Reference Report and supporting documentation.

ONR's GDA process calls for an assessment of the RP's submissions, which increases in detail as the project progresses. The focus of my assessment in this step was to support ONR's decision on the fundamental adequacy of the BWRX-300 design and safety case, and the suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and generic safety, security and safeguards cases.

I targeted my assessment, in accordance with my assessment plan, at the areas that were fundamental to the acceptability of the design and methods for deployment in Great Britain (GB), benchmarking my regulatory judgements against the expectations of ONR's Safety Assessment Principles (SAPs), Technical Assessment Guides (TAGs) and other guidance which ONR regards as relevant good practice, such as International Atomic Energy Agency (IAEA) safety, security and safeguards standards. Where appropriate, I have also considered how I could use relevant learning and regulatory conclusions from the UK Advanced Boiling Water Reactor (UK ABWR) to inform my assessment of the BWRX-300.

I targeted the following aspects in my assessment of the BWRX-300 SSSE:

- The RP's approach to identification, screening and characterisation of external hazards.
- The UK BWRX-300 Generic Site Envelope (GSE) and whether this is likely to be suitably bounding of potential UK site conditions.
- How the UK BWRX-300 GSE aligns with the BWRX-300 Standard Plant Design (SPD) parameters.
- The RP's approach to consideration of climate change.
- The RP's approach for cliff-edge effects and margins beyond the design basis.
- The RP's approach for combined hazards.

- How external hazards have been incorporated into the layout and design of the BWRX-300.

- How building below ground level (referred to as below grade throughout the report) has impacted the design from an external hazards perspective.

- The RP's progress to develop a strategy for how risks can be reduced as low as reasonably practicable (ALARP) at a future stage of the design.

Based upon my assessment, I have concluded the following:

- The design and external hazards aspects of the safety case presented at Step 2 are at an early stage of design maturity. Further development of the design and safety case is required, at a future stage, including site-specific and deterministic analysis to meet UK regulatory expectations. For external hazards, this is particularly important as a future licensee will need to demonstrate the suitability of a site for deployment of the BWRX-300 design. I am satisfied that the RP has identified the main areas for further development, in relation to external hazards, as part of its Forward Action Plan (FAP), and that these can be resolved as part of a future Step 3 GDA or future site-specific activities.

- The RP has provided its approach to assessment of external hazards, which will form the basis for a future external hazards safety case. Detailed methodologies, including those for individual hazards, were not available during Step 2. I am satisfied that appropriate external hazards have been considered for hazard identification and screening during Step 2 of this GDA. In relation to the external hazards assessment for the BWRX-300, I am satisfied that the RP has identified areas for further development, as part of its FAP, and that these could be resolved as part of a future Step 3 GDA or future site-specific activities.

- The RP has defined a UK GSE for the BWRX-300 design. I have compared the GSE values proposed by the RP, to those of existing licensees and previous GDA GSEs and I have found these comparable. The BWRX-300 UK GSE values therefore appear to bound the sites set out in the National Policy Statement for nuclear power generation (EN-6) for those eleven external hazards within the scope of GDA. Overall, I consider that the RP's GSE for the external hazards within scope of this GDA, and for specific external hazards where reassurance has been provided during GDA (seismic and aircraft impact), is appropriate for a two-step GDA.

- For those external hazards where a BWRX-300 UK GSE value has been defined, I am satisfied that they are bounded by the standard plant design (SPD) parameters, with the exception of high air temperature. I judge that this is not a fundamental shortfall, and I am content that this can be resolved as part of a future Step 3 GDA or future site-specific activities. I am satisfied that the RP has identified areas for further development, as part of its FAP, including the demonstration that the BWRX-300 UK GSE values are bounded by the associated SPD parameters, to be addressed as part of a future Step 3 GDA or future site-specific activities.

- The RP has considered climate change for relevant external hazards that may be affected by it. I am satisfied that the RP’s approach to climate change is aligned with previous GDAs and takes account of the most recent UK Climate Projections.

- There is limited information available on the RP’s work on hazard combinations, cliff-edge effects and beyond design basis margins within this GDA. I have identified examples, such as for seismic hazards, where there is additional resilience incorporated in the BWRX-300 design, beyond the design basis, which provides confidence in the design. I am satisfied that the RP has identified areas for further development on these topics, as part of its FAP, and that these could be addressed as part of a future Step 3 GDA or future site-specific activities.

- With the currently available information from the safety case, and assurance gained during this two-step GDA, I am content with the development of the fundamental adequacy of the design and safety case in the external hazards area.

Overall, based on my assessment to date I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design; noting that any decision to permission a BWRX-300 will require further assessment (in either a future Step 3 GDA or during site-specific activities) of suitable and sufficient supporting evidence that can substantiate the claims and proposals made in the GDA Step 2 submissions.

List of abbreviations

ABWR	Advanced Boiling Water Reactor
ALARP	As Low As Reasonably Practicable
ASCE	American Society of Civil Engineers
BDB	Beyond Design Basis
BDBA	Beyond Design Basis Accidents
BL	Baseline
BWR	Boiling Water Reactor
C&I	Control and Instrumentation
CAE	Claim, Argument and Evidence
CNI	Chief Nuclear Inspector
CNSC	Canadian Nuclear Safety Commission
DAC	Design Acceptance Confirmation
DBE	Design Basis Earthquake
DEC	Design Extension Conditions
DESNZ	Department for Energy Security and Net Zero
DRR	Design Reference Report
EN-6	National Policy Statement for Nuclear Power Generation (applicable to listed nuclear projects capable of being deployed by the end of 2025)
EN-7	National Policy Statement for Nuclear Energy Generation (applicable to nuclear power stations expected to be deployed beyond 2025)
ESBWR	Economic Simplified Boiling Water Reactor
EUR	European Utility Requirements
FAP	Forward Action Plan
GB	Great Britain
GDA	Generic Design Assessment
GDRS	Generic Design Response Spectra
GIC	Geomagnetically Induced Currents
GSE	Generic Site Envelope
GVHA	GE Vernova Hitachi Nuclear Energy Americas LLC
HVAC	Heating, Ventilation and Air-Conditioning
IAEA	International Atomic Energy Agency
LOOP	Loss of Off-Site Power
MCR	Main Control Room
MDSL	Master Document Submission List
NPP	Nuclear Power Plant
NPS	National Policy Statement
NRW	Natural Resources Wales
OBE	Operating Basis Earthquake
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PA	Protected Areas
PCSR	Pre-Construction Safety Report
PER	Preliminary Environmental Report
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Assessment

PSAR	Preliminary Safety Analysis Report
PSR	Preliminary Safety Report
RCP	Representative Concentration Pathway
RGP	Relevant Good Practice
RITE	Risk Informed, Targeted Engagements
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
RW	Radioactive Waste
SAP	Safety Assessment Principle(s)
SCR	Secondary Control Room
SBWR	Simplified Boiling Water Reactor
SMR	Small Modular Reactor
SPD	Standard Plant Design
SSC	Structure, System and Component
SSSE	Safety, Security, Safeguards and Environment Cases
TAG	Technical Assessment Guide(s) (ONR)
TSC	Technical Support Contractor
UK	United Kingdom
UK ABWR	United Kingdom Advanced Boiling Water Reactor
UKCP	UK Climate Projections
UKCP18	UK Climate Projections 2018
US	United States of America
USNRC	United States Nuclear Regulatory Commission
V/H	Vertical-to-horizontal
WENRA	Western European Nuclear Regulators’ Association

Contents

1. Introduction

1. This report presents the outcome of my external hazards assessment of the BWRX-300 design as part of Step 2 of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA). My assessment is based upon the information presented in the safety, security, safeguards and environment cases (SSSE) head document (ref. [1]), specifically chapters 1, 2, 3, 9B, 15.1, 15.6, 15.8 and 27 (refs. [2], [3], [4], [5], [6], [7], [8], [9]) the associated revision of the Design Reference Report (DRR) (ref. [10]) and supporting documentation.

2. Assessment was undertaken in accordance with the requirements of ONR's Management System and follows ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [11]) and ONR's risk informed, targeted engagements (RITE) guidance (ref. [12]). The ONR Safety Assessment Principles (SAPs) (ref. [13]), together with supporting Technical Assessment Guides (TAGs) (ref. [14]), have been used as the basis for this assessment.

3. This is a Major report (as per ONR's guidance, NS-TAST-GD-108 (ref. [15])).

1.1. Background

4. The ONR's GDA process (ref. [16]) calls for an assessment of the Requesting Party's (RP) submissions with the assessments increasing in detail as the project progresses. This GDA will be finishing at Step 2 of the GDA process. For the purposes of the GDA, GE Vernova Hitachi Nuclear Energy International LLC (UK Branch) is the RP. GE Vernova Hitachi Nuclear Energy Americas LLC (GVHA) is a provider of advanced reactors and nuclear services, and is the designer of the BWRX-300. GVHA is headquartered in Wilmington, North Carolina, United States of America (US).

5. In Step 1, and for the majority of Step 2, the RP was known as GE-Hitachi Nuclear Energy International LLC, UK Branch, and GVHA as GE-Hitachi Nuclear Energy Americas LLC. The entities formally changed names in October 2025 and July 2025 respectively. The majority of the submissions provided by the RP during GDA were produced prior to the name change, and thus the reference titles in Section 6 of this report reflects this.

6. In the UK, the RP has been supported by its supply chain partner, Amentum, who has assisted the RP in the development of the UK-specific chapters of the SSSE, and other technical documents for the GDA.

7. In January 2024 ONR, together with the Environment Agency and Natural Resources Wales began Step 1 of this two-Step GDA for the generic BWRX-300 design.

8. Step 1 is the preparatory part of the design assessment process and is mainly associated with initiation of the project and preparation for technical

assessment in Step 2. Step 1 completed in December 2024. Step 2 is the first substantive technical assessment step, and began in December 2024 and will complete in December 2025.

9. The RP has stated that at this time it has no plans to undertake Step 3 of GDA and obtain a Design Acceptance Confirmation (DAC). It anticipates that any further assessment by the UK regulators of the BWRX-300 design will be on site-specific basis and with a future licensee.

10. The focus of ONR's assessment in Step 2 was:

- The fundamental adequacy of the design and safety, security and safeguards cases; and

- The suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and cases.

11. The objective is to undertake an assessment of the design against regulatory expectations to identify any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the design.

12. Prior to the start of Step 2 I prepared a detailed Assessment Plan for external hazards (ref. [17]). This has formed the basis of my assessment and was also shared with the RP to maximise openness and transparency.

13. This report is one of a series of assessments which support ONR's overall judgements at the end of Step 2 which are recorded in the Step 2 Summary Report (ref. [18]) and published on the regulators' website.

1.2. Scope

14. The assessment documented in this report is based upon the SSSE for the BWRX-300 (refs. [1], [2], [3], [4], [5], [6], [7], [8], [9], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48]).

15. The RP's GDA scope has been agreed between the regulators and the RP during Step 1. This is documented in an overall Scope of Generic Design Assessment report (ref. [49]). This is further supported by its DRR (ref. [10]) and the Master Document Submission List (MDSL) (ref. [50]). The GDA scope report documents the submissions which were provided in each topic area during Step 2 and provides a brief overview of the physical and functional scope of the Nuclear Power Plant (NPP) that is proposed for consideration in the GDA. The DRR provides a list of the systems, structures and components (SSCs) which are included in the scope of the GDA, and their relevant GDA reference design documents.

16. The RP has stated it does not have any current plans to undertake GDA beyond Step 2. This has defined the boundaries of the GDA and therefore of my own assessment.

17. The GDA scope includes the Power Block (comprising the Reactor Building, Turbine Building, Control Building, Radwaste Building, Service Building, Reactor Auxiliary Structures) and Protected Areas (PA) as well as the balance of plant. It includes all modes of operation.

18. The regulatory conclusions from GDA apply to everything that is within the GDA scope. However, ONR does not assess everything within it or all matters to the same level of detail. This applies equally to my own assessment, and I have followed ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (ref. [11]) and ONR's guidance on Risk Informed, Targeted Engagements (ref. [12]).

19. As appropriate for Step 2 of the GDA, information has not been submitted for all aspects within the GDA Scope during Step 2. The following aspects of the SSSE are therefore out of scope of this assessment:

- The adequacy of the detailed methodologies for identification, screening and characterisation of external hazards. The RP's overall hazard assessment approach was provided as part of this GDA, and I have considered this as part of my assesssment.

- The adequacy of methodologies for individual external hazards, as these were not provided as part of this GDA. Where more information has been provided for some hazards (such as seismic hazards and aircraft impact), I have considered this as part of my assessment.

- Detailed information on site-specific external hazards, including those where some reassurance can be provided during GDA or those external hazards that are bounded by other hazards. Some information was provided on these hazards as part of GDA, but I did not target these as part of my assessment. My assessment focused on the eleven external hazards that the RP has screened within the scope of GDA, with some additional commentary provided on seismic hazards and aircraft impact (both accidental and malicious) given their importance in the civil engineering design.

- The RP's identifcation of hazard combinations that may impact the BWRX-300 design. Within the scope of GDA, an overall approach to combined hazards has been provided but identification of credible hazard combinations was out of scope.

20. My assessment considered the following aspects:

- The RP's overall approach to identification, screening and characterisation of external hazards, including consideration of the eleven external hazards that have been screened into this GDA, in addition to seismic hazards and aircraft impact (both accidental and malicious).

- From an external hazards perspective, whether the design is likely to be capable of being built and operated on a GB site bounded by the generic site envelope (GSE), in a way that is acceptably safe and secure.
- How the UK BWRX-300 GSE compares with the BWRX-300 Standard Plant Design (SPD) parameters.
- The RP’s approach to consideration of climate change.
- The RP’s approach for cliff-edge effects and margins beyond the design basis.
- The RP’s approach for combined hazards.
- How external hazards have been incorporated into the layout and design of the BWRX-300 design and any impacts associated with a compact design.
- How building below ground level (referred to as below grade for the rest of this report) has impacted the design from an external hazards perspective.
- The RP’s progress to develop a strategy for how risks can be reduced as low as reasonably practicable (ALARP) at a future stage of the design.

2. Assessment standards and interfaces

21. The primary goal of the GDA Step 2 assessment is to reach an independent and informed judgment on the adequacy of the RP's SSSE for the reactor technology being assessed.

22. ONR has a range of internal guidance to enable inspectors to undertake a proportionate and consistent assessment of such cases. This section identifies the standards which have been considered in this assessment. This section also identifies the key interfaces with other technical topic areas.

2.1. Standards

23. The ONR SAPs (ref. [13]) constitute the regulatory principles against which the RP's case is judged. Consequently, the SAPs are the basis for ONR's assessment and have therefore been used for the Step 2 assessment of the BWRX-300.

24. The International Atomic Energy Agency (IAEA) safety standards (ref. [51]) and nuclear security series (ref. [52]) are a cornerstone of the global nuclear safety and security regime. They provide a framework of fundamental principles, requirements and guidance. They are applicable, as relevant, throughout the entire lifetime of facilities and activities.

25. ONR is a member of the Western European Nuclear Regulators Association (WENRA). WENRA has developed Reference Levels (ref. [53]), which represent good practices for existing nuclear power plants, and Safety Objectives for new reactors (ref. [54]).

26. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and expanded on in the TAGs (ref. [14]). The TAGs provide the principal means for assessing the external hazards aspects in practice.

27. The key guidance is identified below and referenced where appropriate within Section 4 of this report. Relevant good practice, where applicable, has also been cited within the body of this report.

2.1.1. Safety Assessment Principles (SAPs)

28. The key SAPs applied within my assessment are:

- EHA.1 (Identification and characterisation) and EHA.19 (Screening) - This is relevant to the BWRX-300 hazard assessment approach, for both internal and external hazards.

- EHA.2 (Data sources) and EHA.11 (Weather conditions) - This is relevant to the RP's use of data when defining BWRX-300 UK GSE values and the RP's approach to consideration of climate change in the BWRX-300 UK GSE.

- EHA.3 (Design basis events) and EHA.4 (Frequency of initiating event) – This is relevant where the RP has defined BWRX-300 UK GSE values as part of this GDA.

- EHA.6 (Analysis) - This is relevant where the RP has analysed the potential effects of external hazards that could affect the BWRX-300 design, including combinations of hazards.

- EHA.7 ('Cliff-edge' effects) and EHA.18 (Beyond design basis events) – This is relevant where there may be an increase in radiological consequences beyond the design basis, and the BWRX-300 design would need to demonstrate that there are no cliff-edge effects.

- EHA.8 (Aircraft crash) – This is relevant where the RP has developed its protection strategy for the BWRX-300 design against accidental and malicious aircraft impact, although the total predicted frequency of aircraft crash has not yet been defined.

- EHA.9 (Earthquakes) – This is relevant where claims are made that the BWRX-300 UK GSE value for seismic hazards would be suitably bounding of a potential GB site.

- EHA.12 (Flooding) – This is relevant where claims are made that plant grade is above the design flood level and that there are no external flooding protection features in the BWRX-300 design.

- ELO.4 (Minimisation of the effects of incidents) – This is relevant as a more compact layout is adopted in the BWRX-300 design, when compared with larger reactor designs. The majority of the reactor building is below grade, and the potential impacts of this are relevant from an external hazards perspective.

- SC.2 (Safety case process outputs) – This is relevant for the development of the RP's safety case including the Claims, Arguments, Evidence (CAE) structure and ensuring that the safety case is clear, logically structured and easily accessible to those who need to use it.

29. A list of the SAPs used in this assessment is recorded in Appendix 1.

2.1.2. Technical Assessment Guides (TAGs)

30. The following TAGs have been used as part of this assessment:

- NS-TAST-GD-004 - Fundamental Principles of safety assessment (ref. [55]).

- NS-TAST-GD-005 - Regulating duties to reduce risks ALARP (ref. [56]).
- NS-TAST-GD-013 - External hazards (ref. [57]).
- NS-TAST-GD-051 - The purpose, scope and content of safety cases (ref. [58]).
- NS-TAST-GD-096 - Guidance on Mechanics of Assessment (ref. [11]).

2.1.3. Joint regulatory guidance on climate change

31. The following joint regulatory guidance on climate change has been used as part of this assessment:

- Principles for Flood and Coastal Erosion Risk Management (ref. [59]).
- Use of UK Climate Projections 2018 (UKCP18) Position Statement (ref. [60]).

32. I have also taken cognisance of the findings of ONR’s Chief Nuclear Inspector’s (CNI) themed inspection on climate change, the summary report for which was published in July 2025 (ref. [61]).

2.1.4. National and international standards and guidance

33. The following international standards and guidance have been used as part of this assessment:

- IAEA SSR-2/1 - Safety of Nuclear Power Plants: Design (ref. [62]).
- IAEA GSR Part 4 - Safety Assessment for Facilities and Activities (ref. [63]).
- IAEA SSG-2 - Deterministic Safety Analysis for Nuclear Power Plants (ref. [64]).
- IAEA SSG-30 - Safety Classification of Structures, Systems and Components in Nuclear Power Plants (ref. [65]).
- IAEA SSG-61 - Format and Content of the Safety Analysis Report for Nuclear Power Plants (ref. [66]).
- IAEA SSG-64 - Protection against Internal Hazards in the Design of Nuclear Power Plants (ref. [67]).
- IAEA SSG-67 - Seismic Design for Nuclear Installations (ref. [68]).
- IAEA SSG-68 - Design of Nuclear Installations Against External Events Excluding Earthquakes (ref. [69]).

- IAEA SSG-77 - Protection Against Internal and External Hazards in the Operation of Nuclear Power Plants (ref. [70]).
- IAEA TECDOC-1936 - Applicability of design safety requirements to small modular reactor technologies intended for near term deployment (ref. [71]).
- WENRA Safety Reference Levels for Existing Reactors 2020 (ref. [53]).
- WENRA Safety of New Nuclear Power Plant Designs (ref. [54]).
- WENRA Report on Applicability of the Safety Objectives to Small Modular Reactors (ref. [72]).
- WENRA Guidance on Issue TU: External Hazards Head Document (ref. [73]).
- WENRA Guidance on Seismic Events (ref. [74]).
- WENRA Guidance on Extreme Weather Conditions (ref. [75]).
- WENRA Guidance on External Flooding (ref. [76]).

2.2. Integration with other assessment topics

34. To deliver the assessment scope described above I have worked closely with a number of other topics to inform my assessment. Similarly, other assessors sought input from my assessment. These interactions are key to the success of GDA to prevent or mitigate any gaps, duplications or inconsistencies in ONR's assessment.

35. The key interactions with other topic areas were:

- **Civil engineering** – I collaborated with civil engineering on the impact of the hazard load on the civil engineering structures, and the hazard assessment approach for seismic and aircraft impact (both accidental and malicious) hazards.
- **Control and instrumentation (C&I)** – The C&I inspector led on the RP's approach to the proposed resilience of C&I equipment in the Reactor Building to external hazards, in particular seismic hazards.
- **Electrical engineering** – The electrical engineering inspector led on the seismic resilience of electrical aspects of systems and loss of off-site power (LOOP).
- **Human factors** – The human factors inspector led on the locations of the Main Control Room (MCR) and Secondary Control Room (SCR) in

relation to protection of personnel in the MCR and SCR in a seismic event.

- **Internal hazards** – I collaborated with internal hazards on the approach for combined hazards.

- **Probabilistic Safety Assessment (PSA)** – The PSA inspector led the assessment of the external hazards PSA, focusing on the conclusions from the seismic hazards PSA and high winds PSA. This informed my assessment of the deterministic aspects of the safety case.

2.3. Use of technical support contractors

36. During Step 2, Technical Support Contractors (TSCs) supported some aspects of the assessment for civil engineering for the BWRX-300 GDA. The TSCs indirectly supported my external hazards assessment, through the development of Regulatory Queries (RQs) related to areas of overlap between the two topics (seismic and geological hazards, and aircraft impact). It should be noted that all regulatory judgements have been made exclusively by ONR.

3. Requesting Party's submission

37. The RP submitted the SSSE at the start of Step 2 in four volumes that integrate environmental protection, safety, security, and safeguards. This was accompanied by a head document (ref. [1]), which presents the integrated GDA environmental, safety, security, and safeguards case for the BWRX-300 design.

38. All four volumes were subsequently consolidated to incorporate any commitments and clarifications identified in regulatory engagements, regulatory queries and regulatory observations, and were resubmitted in July 2025. This consolidated revision is the basis of the regulatory judgements reached in Step 2.

39. This section presents a summary of the RP's safety case for external hazards. It also identifies the documents submitted by the RP which have formed the basis of my Step 2 assessment of the BWRX-300 design.

3.1. Summary of the BWRX-300 Design

40. The BWRX-300 is a single unit, direct-cycle, natural circulation, boiling water reactor with a power of ~870 MW (thermal) and a generating capacity of ~300 MW (electrical) and is designed to have an operational life of 60 years. The RP claims the design is at an advanced concept stage of development and is being further developed during the GDA in parallel with the RP's SSSE.

41. The BWRX-300 is the tenth generation of the boiling water reactor (BWR) designed by GVHA and its predecessor organisations. The BWRX-300 design builds upon technology and methodologies used in its earlier designs, including the Advanced Boiling Water Reactor (ABWR), Simplified Boiling Water Reactor (SBWR) and the Economic Simplified Boiling Water Reactor (ESBWR). The ABWR has been licensed, constructed and is currently in operation in Japan, and a UK version of the design was assessed in a previous GDA with a view to potential deployment at the Wylfa Newydd site. Neither the SBWR or ESBWR have been built or operated.

42. The BWRX-300 reactor core houses 240 fuel assemblies and 57 control rods inside a steel reactor pressure vessel (RPV). It uses fuel assemblies (GNF2) that are already currently widely used globally (ref. [19]).

43. The reactor is equipped with several supporting systems for normal operations and a range of safety measures are present in the design to provide cooling, control criticality and contain radioactivity under fault conditions. The BWRX-300 utilises natural circulation and passive cooling rather than active components, reflecting the RP's design philosophy.

44. The following aspects of the design are relevant from an external hazards perspective:

- The majority of the Reactor Building is below grade. The impacts of external hazards will be different to a plant built fully above grade. The impacts of external hazards will likely be reduced for some external hazards such as seismic hazards, air temperature, wind and some industrial hazards. In the BWRX-300 SPD, the maximum flood height is below grade (ref. [8]). The RP states that the Power Block structures (including the Reactor Building) remain accessible during flooding events because plant grade is above the design flood level. There are no external flooding protection features in the BWRX-300 design, no permanent dewatering system and all exterior openings and penetrations for the Reactor Building are above grade (refs. [4], [8]). A requirement has however, been identified to develop site-specific flood protection measures that ensure suitable water tightness flood protection measures, which I expect would be addressed as part of FAP PSR 15.8-144 (ref. [8]). The impacts of the below grade design of the Reactor Building for seismic hazards are discussed further in the ONR civil engineering assessment report (ref. [77]).

- The BWRX-300 containment structure, containment internal structures and the Reactor Building are the only Seismic Category 1A civil structures in the BWRX-300 design (ref. [4]). These structures/buildings are passive structures and components that are required to remain structurally intact during and after a seismic event (ref. [4]). Surrounding buildings and their SSCs are evaluated for seismic interaction to ensure that they will not collapse or collide with Seismic Category 1 SSCs and that they will maintain their stability during a Design Basis Earthquake (DBE) or other relevant extreme external hazard event (ref. [4]).

- The MCR is located in the Control Building, which is a Seismic Category 2 structure (ref. [4]). In addition to the seismic interactions described above, the Control Building is evaluated for seismic interaction to ensure that the Control Building structure does not collapse and result in incapacitating injury to MCR occupants or prevent their egress to the Reactor Building (ref. [4]). The SCR is located in the Reactor Building which is a Seismic Category 1A structure. This is discussed further in the ONR civil engineering and human factors assessment reports (refs. [77], [78]).

- In the BWRX-300 SPD, the RP states that SSCs seismically categorised as Seismic Category Radioactive Waste (RW) (such as the Radioactive Waste Building) are seismically qualified for one half of the site-specific DBE (ref. [4]). The RP states that the Radioactive Waste Building is currently assessed against half of the Probable Maximum Flood[1] height within the BWRX-300 SPD given the claimed low unmitigated radiological consequences of faults in this building (ref. [8]). This is based on the expectations set out in United States Nuclear Regulatory Commission (US NRC) design guidance for radioactive waste management SSCs (ref. [79]). The RP has identified forward work through the Forward Action Plan (FAP), outside the scope of this GDA, to confirm if this is appropriate within a GB context (see also section 4.3.4.1).

- The compact layout of the BWRX-300 design is of note, compared to a larger gigawatt reactor. The proximity and arrangement of SSCs affects the outcomes for various external hazards such as seismic hazards and aircraft impact. The BWRX-300 design against hazards is based upon separation and segregation of equipment to limit the effects of hazards to one division, where possible (ref. [80]). Where hazards cannot be segregated, SSCs required to function during or after the hazard are qualified to function under specific conditions (ref. [80]). If it is not possible to protect SSCs through segregation or qualification, these are considered as Beyond Design Basis (BDB) hazards within the BWRX-300 design (ref. [80]).

3.2. BWRX-300 Case Approach and Structure

45. The RP has submitted information on its strategy and intentions regarding the development of the SSSE (refs. [81], [82], [83], [84]). This was submitted to ONR during Step 1.

46. The RP has submitted a SSSE for the BWRX-300 that claims to demonstrate that the standard BWRX-300 can be constructed, operated, and decommissioned on a generic site in GB such that a future licensee will be able to fulfil its legal duties for activities to be safe, secure and will protect people and the environment. The SSSE comprises a Preliminary Safety Report (PSR) which also includes information on its approach to safeguards and security, a security assessment, and a Preliminary Environment Report (PER), and their supporting documents.

47. The format and structure of the PSR largely aligns with the IAEA guidance for safety cases, SSG-61 (ref. [66]), supplemented to include UK specific chapters such as Structural Integrity and Chemistry. The RP has also provided a chapter on As Low as Reasonably Practicable (ALARP), which is applicable to all safety chapters. The RP has stated that the design and analysis referenced in the PSR is consistent with the March 2024 Preliminary Safety Analysis Report (PSAR) submitted to the US NRC. The

[1] The term “Probable Maximum Flood” was developed by the U.S. Army Corps of Engineers, and has been used by US NRC since 1970 (refs. [125], [126]).

Security Assessment and PER are for the same March 2024 design but have more limited links to any US or Canadian submissions.

3.3. Summary of the RP's case for external hazards

48. The aspects covered by the BWRX-300 safety case in the area of external hazards can be broadly grouped under seven headings which are summarised in sections 3.3.1 to 3.3.7 below.

49. The top-level claims relevant for external hazards are:

- **Claim 2** - The safety risks to workers and the public during the construction, commissioning, operation and decommissioning of the BWRX-300 have been reduced as low as reasonably practicable.

- **Claim 2.3** - A suitable and sufficient safety analysis has been undertaken which presents a comprehensive fault and hazard analysis that specifies the requirements on the safety measures and informs emergency arrangements.

3.3.1. Identification and screening of external hazards

50. The RP's design basis hazard assessment approach (ref. [80]) covers hazard identification and screening for the purpose of GDA. The RP's criteria for screening out external hazards (refs. [8], [85]) are:

- Low frequency – The RP describes this as the frequency of exceedance is below one in ten million years per annum; or

- Bounded hazard – The RP defines this as "where the failures caused by the hazard are bounded by another hazard of similar consequence and higher frequency".

51. The RP has screened external hazards into four groups (ref. [8]):

- Within scope of GDA (eleven external hazards);

- Site-specific but reassurance can be provided during GDA (twenty-six external hazards);

- Site-specific (forty external hazards); or

- Bounded by another hazard(s) (five external hazards).

52. The outputs of the external hazards identification and screening is presented in Appendix C of Chapters 2 and 15.8 of the PSR (refs. [3], [8]) and in Appendix 2 of this assessment report.

53. The relevant claims and arguments from the PSR are:

- **Claim 2.3.1** - All initiating events with the potential to lead to significant radiation exposure or release of radioactive material, including the effects of internal and external hazards have been identified and appropriately assessed.
    - **Argument 2.3.1.1** - National and international guidance has been used to derive a comprehensive list of external hazards for consideration. Screening and grouping has been applied to identity those which require safety assessment.

3.3.2. External Hazards Analysis and Combined Hazards

54. The RP's deterministic assessment of external hazards is set out in Chapter 15.8 of the PSR (ref. [8]), whilst the RP's probabilistic assessment of external hazards is set out in Chapter 15.6 of the PSR (ref. [7]). The RP has identified that further work is required to develop both the deterministic and probabilistic assessment of external hazards. This is identified in the FAP in the PSR (refs. [7], [8]), to be addressed in a future version of the safety case, after Step 2 of GDA.

55. The RP submitted a topic report for combined hazards (ref. [86]), which provides a description of the combined hazards identification and assessment process for the BWRX-300 design. The identification of credible hazard combinations was out of scope for this GDA (ref. [49]).

56. The RP's topic report for combined hazards (ref. [86]) identifies that further work is required for both individual hazards and combined hazards. This is identified in the FAP in the combined hazards topic report (ref. [86]) and in the relevant sections of the PSR (refs. [7], [8], [35]), to be addressed in a future version of the safety case, after Step 2 of GDA.

57. The relevant claims and arguments from the PSR are:

- **Claim 2.3.1** - All initiating events with the potential to lead to significant radiation exposure or release of radioactive material, including the effects of internal and external hazards have been identified and appropriately assessed.
    - **Argument 2.3.1.1** - National and international guidance has been used to derive a comprehensive list of external hazards for consideration. Screening and grouping has been applied to identity those which require safety assessment.
- **Claim 2.3.2** - Design basis events have been appropriately assessed to specify requirements on safety functions and on safety measures and assess their effectiveness.

- **Argument 2.3.2.1** - All mechanisms by which each individual or combinations of external hazards could challenge Fundamental Safety Functions have been identified.

- **Argument 2.3.2.2** - Protection measures which ensure delivery of Fundamental Safety Functions following a design basis external hazard event are identified and analysed using conservative assumptions.

- **Argument 2.3.2.3** - Operational or human actions to mitigate the effects of external hazards on the plant have been identified where relevant.

3.3.3. Generic Site Envelope (GSE)

58. The RP has defined a UK GSE for the BWRX-300 design within this two-step GDA. The GSE was initially defined in Step 1 in the Generic Site Envelope and External Hazards Identification Report (ref. [85]). Some information within this report was updated in Step 2 by Chapters 2 and 15.8 of the PSR (refs. [3], [8]).

59. The RP has defined generic site values for the UK BWRX-300 GSE which represent the envelope of potential GB site conditions. For the purposes of this GDA, the RP has considered the eight GB sites set out in the National Policy Statement (NPS) for nuclear power generation (EN-6) (ref. [87]). The RP has selected GSE values intended to bound all eight of these GB sites. The RP has assumed that the generic site is a coastal GB site using a once through cooling system with seawater as the ultimate heat sink (ref. [85]).

60. At the time of this GDA, EN-6 was only applicable to nuclear projects capable of being deployed in the UK by the end of 2025, which would not apply to the BWRX-300 design. The new NPS for nuclear energy generation (EN-7) is intended to be applicable to nuclear power stations expected to be deployed in the UK beyond 2025 (ref. [88]). EN-7 has not been published at the time of authoring this report.

61. The relevant claims and arguments from the PSR are:

- **Claim 2.3.1** - All initiating events with the potential to lead to significant radiation exposure or release of radioactive material, including the effects of internal and external hazards have been identified and appropriately assessed.

    - **Argument 2.3.1.3** - A Generic Site Envelope has been developed to characterise and provide bounding design basis hazard magnitudes for EN-6 UK coastal sites. Those hazards which are site-specific and cannot be generically characterised are also identified. These will be fully characterised when a site is selected.

3.3.4. Consideration of climate change in the GSE

62. The RP has considered climate change over the lifetime of the plant, which is assumed to be until approximately the year 2100, after decommissioning (ref. [8]). The RP has considered the impacts of climate change for air temperature, rainfall intensity, sea water temperature, wind speed, storm frequency and lightning, snow loading and drifting, and humidity (ref. [8]).

63. The RP has provided climate change adjustments for relevant external hazards, using the UK Climate Projections 2018 (UKCP18) (ref. [89]), derived by the Met Office. UKCP18 uses Representative Concentration Pathways (RCPs) with four radiative forcing scenarios: RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. RCPs specify the concentrations of greenhouse gases that will result in the total radiative forcing increasing by a specified amount by the year 2100, relative to pre-industrial levels (ref. [90]). Total radiative forcing is the difference between the incoming and outgoing radiation at the top of the atmosphere (ref. [90]).

64. The RP has used RCP 6.0 at the 90th percentile to derive climate change adjustments for the BWRX-300 GDA, for relevant external hazards. For some hazards, RCP 6.0 data is not available and alternative RCPs have been used (either RCP 4.5 or RCP 8.5). Where parameters are not covered by UKCP18, the RP states that best available data has been used. This is identified in the FAP in Chapter 15.8 of the PSR (ref. [8]) to be addressed in a future version of the safety case, after Step 2 of GDA.

65. The relevant claims and arguments from the PSR are:

- **Claim 2.3.1** - All initiating events with the potential to lead to significant radiation exposure or release of radioactive material, including the effects of internal and external hazards have been identified and appropriately assessed.
    - **Argument 2.3.1.3** - A Generic Site Envelope has been developed to characterise and provide bounding design basis hazard magnitudes for EN-6 UK coastal sites. Those hazards which are site-specific and cannot be generically characterised are also identified. These will be fully characterised when a site is selected.

3.3.5. Standard plant design (SPD) parameters

66. The objective of the RP is to develop a standard plant design (SPD) that could be licensed in multiple locations including the US, Canada and Europe. To achieve this goal the RP claims its plant design has, wherever possible, been developed to meet the IAEA safety standards. SPD parameters are defined as those parameters that are adopted in the standard plant design for the BWRX-300.

67. The RP has defined SPD parameters for some external hazards for the BWRX-300 design, as part of the BWRX-300 plant architecture definition (ref. [91]). These are intended to be applicable to the BWRX-300 design in any country of deployment and will be used to develop individual system requirements.

68. Table D-2 of PSR Chapter 15.8 (ref. [8]) compares the BWRX-300 UK GSE values with the SPD parameters for some external hazards. This is summarised in Appendix 3 of this assessment report. Durations and return frequencies are not always directly comparable between the BWRX-300 UK GSE values and the SPD parameters.

69. The relevant claims and arguments from the PSR are:

- **Claim 2.3.1** - All initiating events with the potential to lead to significant radiation exposure or release of radioactive material, including the effects of internal and external hazards have been identified and appropriately assessed.
    - **Argument 2.3.1.3** - A Generic Site Envelope has been developed to characterise and provide bounding design basis hazard magnitudes for EN-6 UK coastal sites. Those hazards which are site-specific and cannot be generically characterised are also identified. These will be fully characterised when a site is selected.

3.3.6. Cliff-edge effects and margins beyond the design basis

70. Risk contributions from BDB hazards are considered in the PSA chapter of the PSR (ref. [7]) and in the supporting PSA methodology report (ref. [92]). Where sensitivity studies have been undertaken within the PSA, for example for seismic hazards, these do not show any cliff-edge effects (ref. [93]). The RP has provided some qualitative description on cliff-edge effects and BDB margins within Chapter 15.8 of the PSR (ref. [8]).

71. The RP has identified that further work is required to demonstrate the absence of cliff-edge effects and to determine the return frequency at which fundamental safety functions will be lost. This is identified in the FAP in Chapter 15.8 of the PSR (ref. [8]), to be addressed in a future version of the safety case, after Step 2 of GDA.

72. The relevant claims and arguments from the PSR are:

- **Claim 2.3.3** - Beyond Design Basis and Severe Accidents have been appropriately assessed to identify further risk reducing measures and inform emergency arrangements.

  - **Argument 2.3.3.1** - External Hazards with magnitudes just in excess of the Design Basis are analysed and do not result in disproportionate consequences.

  - **Argument 2.3.3.2** - Radiological releases due to Beyond Design Basis External Hazards are shown to be As Low As Reasonably Practicable.

3.3.7. ALARP by Design

73. Claim 2 of the RP's safety case is to reduce risks ALARP:

- **Claim 2**: The safety risks to workers and the public during the construction, commissioning, operation and decommissioning of the BWRX-300 have been reduced as low as reasonably practicable.

74. It was out of the RP's scope for this GDA to provide a full demonstration that the risks to operators and the public from the effects of external hazards on the BWRX-300 are ALARP. Within this GDA, the RP has developed a strategy for how risks can be shown to be ALARP at a future site-specific stage (ref. [9]).

75. The RP has set out in Chapter 15.8 of the PSR (ref. [8]) how it considers that the external hazard assessment approach will contribute to the future demonstration that risks have been reduced ALARP:

- External hazards will be identified and characterised based on RGP. A design basis magnitude for each hazard will be derived, and the plant will be assessed against this using conservative assumptions.

- All credible combinations of external hazards will be identified and assessed.

- SSCs will be designed and qualified with conservatisms and margins.

- Optioneering will be undertaken for any UK-specific design changes to ensure that alternative design solutions are considered, reviewed and ranked prior to the selection of the chosen solution.

- External hazard considerations have been included in the development of the generic site layout for GDA and will be considered further at a site-specific stage, after Step 2 of GDA.

3.4. Basis of assessment: RP's documentation

76. The principal documents that have formed the basis of my external hazards assessment of the SSSE are:

- BWRX-300 UK GDA Scope of Generic Design Assessment (ref. [49]) which sets out the scope for this two-step GDA and the key submissions for each topic area.
- BWRX-300 UK GDA DRR (ref. [10]) which describes the design reference for the BWRX-300 to support this GDA. The DRR also outlines the design control processes used to maintain configuration control for any changes to the Design Reference during this two-step GDA.
- BWRX-300 UK GDA Internal/External Hazard Assessment Approach (ref. [80]) which outlines the approach for design basis hazards and gives an overview of the external hazards requirements and strategy for the BWRX-300.
- BWRX-300 UK GDA GSE and External Hazards Identification report (ref. [85]) which describes the external hazards scope and generic site information for GDA. This report was submitted in Step 1. Some information within this report was updated in Step 2 by Chapters 2 and 15.8 of the PSR (refs. [3], [8]).
- BWRX-300 UK GDA PSR Chapter 2 – Site Characteristics (ref. [3]) which details the site characteristics for a BWRX-300 UK GSE and the outputs of the hazard screening.
- BWRX-300 UK GDA PSR Chapter 3 – Safety Objective and Design Rules for SSCs (ref. [4]) which outlines the approach to categorisation and classification of SSCs, including seismic categorisation. Chapter 3 also sets out the overall protection strategy against external hazards and the general criteria used in the design of BWRX-300 civil structures.
- BWRX-300 UK GDA PSR Chapter 15.8 – Deterministic Safety Analyses - Analysis of External Hazards (ref. [8]) which summarises the deterministic assessment of external hazards and includes information on the BWRX-300 UK GSE for potential GB sites.
- BWRX-300 UK GDA Combined Hazards Topic Report (ref. [86]) which provides a description of the combined hazards identification and assessment process for the BWRX-300.

3.5. Design Maturity

77. My assessment is based on Revision 3 of the DRR (ref. [10]). The design reference report presents the baseline design for GDA Step 2, outlining the physical system descriptions and requirements that form the design at that point in time.

78. The Reactor Building and the Turbine Building, along with the majority of the significant SSCs are housed within the ‘Power Block’. The Power Block also includes the Radioactive Waste Building, the Control Building and a Plant Services Building. For security, this also includes the PA boundary and PA access building.

79. The GDA Scope Report (ref. [49]) describes the RP’s design process that extends from baseline (BL) 0 (where functional requirements are defined) up to BL 3 (where the design is ready for construction).

80. In the March 2024 design reference, SSCs in the Power Block are stated to be at BL1. BL1 is defined as:

- System interfaces established;
- (Included) in an integrated 3D model;
- Instrumentation and control aspects have been modelled;
- Deterministic and probabilistic analysis has been undertaken; and
- System descriptions developed for the primary systems.

81. The balance of plant remains at BL0 for which only plant requirements have been established, and SSC design remains at a high concept level.

4. ONR assessment

4.1. Assessment strategy

82. The objective of my GDA Step 2 assessment was to reach an independent regulatory judgement on the fundamental aspects of the BWRX-300 design, relevant to external hazards as described in sections 1 and 3 of this report. My assessment strategy is set out in this section and defines how I have chosen which matters to target for assessment. My assessment is consistent with the delivery strategy for the GVHA BWRX-300 GDA (ref. [94]).

83. GVHA is currently engaging with regulators internationally, including US NRC and the Canadian Nuclear Safety Commission (CNSC) in Canada. It is proposing a standard BWRX-300 design for global deployment with minimal design variations from country to country. My assessment takes cognisance of work undertaken by overseas regulators where appropriate.

84. Whilst there is no operating BWR plant in the UK, ONR has previously performed a four-step GDA on the Hitachi-GE UK ABWR (ref. [95]). I have taken learning from this previous activity, targeting my assessment on those aspects of the BWRX-300 which are novel or specific to this design. I have not looked to reassess inherent aspects of BWR technology which were considered in significant detail for the UK ABWR and judged to be acceptable.

85. As part of my assessment, I have targeted matters:

- which allow me to form a judgement on the fundamentals of the BWRX-300 design and safety case in line with the objectives of Step 2;
- which I judge to be the most safety significant or where the hazards appear least well controlled in the context of the design and safety case;
- where I consider that justification and scrutiny of the design or safety case may be needed due to factors such as novelty or uncertainty;
- where the BWRX-300 design or safety case differs from established RGP;
- where I consider there to be a significant risk that the fundamental aspect being assessed will not be able to be substantiated or will not meet regulatory expectations in future project stages;
- where I consider that attention is needed on a fundamental aspect of the design or safety case that may prevent construction and operation of the BWRX-300 in GB;
- where I identified items for follow up during Step 1;

- for external hazards where no margin can be demonstrated between the GSE value and the design value;
- for external hazards where the margin between the GSE value and the design value is small;
- for external hazards where the approach to safety is novel; and
- based on the assessment findings from the UK ABWR Step 4 external hazards assessment report (ref. [96]).

4.2. Assessment Scope

86. My assessment scope, and the areas I have chosen to target for my assessment are set out in this section. This section also outlines the submissions that I have sampled, the standards and criteria that I have judged against and how I have interacted with the RP and other assessment topics.

87. My assessment scope is consistent with the GDA scope agreed between the regulators and the RP during Step 1 and detailed in Section 1.2 of this report. I have targeted my assessment within this scope.

88. In line with the objectives for Step 2, I have undertaken a broad review of the highest level, fundamental claims and supporting arguments related to external hazards. To support this, I have sampled a targeted set of the claims or arguments as set out below. Where applicable, I have also sampled the evidence available to support any claims and arguments.

89. In order to fulfil the aims for the Step 2 assessment of the BWRX-300, I have assessed the following items, which I consider important:

- Safety case – I have examined the fundamentals of the BWRX-300 safety case, as appropriate for Step 2.
- Hazard identification and characterisation – I have examined the RP’s approach to hazard identification and characterisation.
- Hazard screening – I have examined the RP’s approach to hazard screening.
- GSE – I have examined the external hazards definitions presented to bound a GB candidate site. I have focused on the eleven external hazards that are within scope of this GDA, and selected site-specific hazards where some reassurance can be provided during GDA (seismic hazards and aircraft impact – both accidental and malicious).

- Hazard combinations – I have examined the RP's combined hazard identification and assessment approach, which I have considered with the internal hazards topic area.

- Consideration of climate change – I have examined the RP's approach to consideration of climate change effects, within the GSE for a potential GB site.

- SPD – I have examined how the external hazard definitions presented as part of the UK BWRX-300 GSE compare to the BWRX-300 SPD parameters, for external hazards within the scope of GDA and for seismic hazards.

- Cliff-edge effects and beyond design basis margins – I have considered the RP's approach to cliff-edge effects and beyond design basis margins, at this stage of the design.

- Leveraging UK ABWR GDA – Where possible, I have considered how I can leverage the UK ABWR GDA as part of my assessment. This includes consideration of external hazards definitions presented as part of the GSE for the UK ABWR GDA, and how they compare to the BWRX-300 UK GSE values, as well as consideration of the UK ABWR GDA assessment findings.

- Plant layout to support resilience to hazards – I have considered how the SSSE and supporting documentation provides evidence of how the RP has optimised the BWRX-300 design to provide resilience against external hazards.

- Future ALARP demonstration – I have considered how the RP is making progress for how risks can be shown to be ALARP at a future site-specific stage.

4.3. Assessment

4.3.1. Safety Case

90. I assessed the RP's SSSE against IAEA standards (refs. [69], [70]), WENRA safety reference levels (ref. [53]) and ONR guidance (refs. [13], [57]). I focused on the fundamental adequacy of the RP's safety case. This included the assessment of the RP's safety case claims, arguments and where relevant, evidence commensurate with Step 2 to demonstrate that external hazards that may have the potential to impact nuclear safety are adequately identified and mitigated.

91. The RP has used a CAE structure, with some evidence provided at Step 2 in support of the Claims and Arguments. The top-level claims relevant for external hazards are:

- **Claim 2** - The safety risks to workers and the public during the construction, commissioning, operation and decommissioning of the BWRX-300 have been reduced as low as reasonably practicable.

- **Claim 2.3** - A suitable and sufficient safety analysis has been undertaken which presents a comprehensive fault and hazard analysis that specifies the requirements on the safety measures and informs emergency arrangements.

92. The RP has provided some evidence in support of Claim 2.3, and the underpinning arguments within this Step 2 GDA. I consider that the RP's safety case philosophy and structure is logical and aligns with the expectations of SAP SC.2 – safety case process outputs (ref. [13]).

93. The RP has identified further work to develop the safety case, as part of a future Step 3 GDA or future site-specific activities, including the development of a safety case manual (FAP PSR 15-3). I have sampled the specification for the safety case manual (ref. [97]) which focuses on areas that need to be addressed as part of the development of a future UK Pre-Construction Safety Report (PCSR). I am satisfied that the RP has acknowledged that further development of the safety case is required, including UK specific areas, and has identified appropriate forward work to address this as part of a future Step 3 GDA or future site-specific activities.

4.3.2. Hazard identification and characterisation

94. The RP's hazard identification process is set out in the GSE and external hazards identification report (ref. [85]) and Chapter 15.8 of the PSR (ref. [8]). The RP states that it has considered international guidance (such as refs. [69], [73]), information from previous UK GDAs and external hazards assessments and ONR guidance (refs. [13], [57]) to identify a list of unscreened external hazards. The list of identified external hazards is presented in Appendix C of Chapters 2 and 15.8 of the PSR (refs. [3], [8]).

95. I am satisfied that the RP has applied an effective process to hazard identification that meets the intent of SAP EHA.1 – identification and characterisation (ref. [13]). The RP has taken account of relevant good practice (RGP) in identifying external hazards that could affect the BWRX-300 design (for example, refs. [57], [68], [69], [73]). I judge that this meets ONR's expectations for external hazards that would typically be relevant to nuclear sites in GB (ref. [57]).

96. The list of identified external hazards does not include some seismic and geological hazards such as capable faulting, liquefaction, ground deformation and settlement. FAP PSR 15.8-144 covers site characterisation

work to develop the site-specific external hazards safety case in support of a potential site licence application and specifically refers to seismic and geological hazards. I do not, therefore, consider this to be a fundamental shortfall.

4.3.3. Hazard screening

97. The RP's categorisation of external hazards for screening is presented in Appendix C of Chapters 2 and 15.8 of the PSR (refs. [3], [8]) and Appendix 2 of this assessment report. The RP has screened external hazards into four groups (ref. [8]):

- Within scope of GDA (eleven external hazards);
- Site-specific but reassurance can be provided during GDA (twenty-six external hazards);
- Site-specific (forty external hazards); or
- Bounded by another hazard(s) (five external hazards).

98. I am satisfied that the RP's categorisation of external hazards for screening is aligned with ONR's GDA Technical Guidance (ref. [98]) [see section 3.3.1 of this assessment report for further details] and I have not identified any significant omissions in the outputs of the RP's screening, presented in Appendix C of Chapters 2 and 15.8 of the PSR (refs. [3], [8]).

99. I note that the RP has excluded external hazards arising from malicious intent from Chapters 2 and 15.8 of the PSR. For external hazards, the RP has considered malicious aircraft impact analysis as out of scope within this GDA (ref. [49]). I would typically expect malicious aircraft impact to be included in the GDA scope for external hazards. For the purposes of this GDA, I have taken confidence from information included in the civil engineering and security sections of the PSR and supporting references. This is discussed further in section 4.3.3.3.2 of this assessment report.

100. I am satisfied that the RP has applied effective hazard screening criteria that meets the intent of SAP EHA.19 – screening (ref. [13]). The RP has not screened out any external hazards at this stage on the basis of low frequency, which I consider to be a reasonable approach for GDA. I consider that the five external hazards which are bounded by another hazard(s) are reasonable for GDA. The RP has taken account of relevant good practice (RGP) in developing screening criteria for external hazards that could affect the BWRX-300 design (for example, refs. [13], [57], [68], [69], [73]).

101. I judge that the outputs of the RP's hazard screening are appropriate and I am satisfied that the RP has categorised those external hazards which are most significant as either 'within scope of GDA' or 'site-specific but reassurance can be provided during GDA'.

102. FAP PSR 15.8-144 covers site characterisation work to develop the site-specific external hazards safety case in support of a potential site licence application (ref. [8]). I expect that this will include those site-specific hazards that were not within scope of this GDA. I am therefore satisfied that this is not a fundamental shortfall arising from the hazard identification and screening process.

4.3.4. Generic site envelope (GSE)

103. For the purposes of this GDA, the RP has considered the eight EN-6 sites (ref. [87]) and has assumed that the generic site is a coastal GB site using a once through cooling system with seawater as the ultimate heat sink (ref. [3]). I consider the RP's approach to be reasonable, given the position with the NPS (EN-6 and EN-7) (refs. [87], [88]) during this GDA.

104. Appendix 3 of this assessment report summarises the BWRX-300 UK GSE values for external hazards within scope of this GDA, and the climate change adjustment (where appropriate) (refs. [3], [8]]). Where BWRX-300 SPD parameters are available, these are also included in Appendix 3 of this assessment report.

105. The RP has defined quantitative BWRX-300 UK GSE values for ten of the eleven external hazards within scope of GDA (fog has not been quantitatively defined) and for seismic hazards. The RP has not quantitatively defined BWRX-300 UK GSE values for any other external hazards within this GDA, except for the malicious aircraft impact hazard where some information was provided in the security report. I consider the RP's approach reasonable for a two-step GDA.

106. Duration is an important parameter when defining external hazards. Within the BWRX-300 UK GSE, the duration is not defined for all extreme variables, where it would typically be expected (for example, wind speed, air temperature). I am satisfied that this is not a fundamental shortfall as the GSE values are comparable with previous GDAs. I would expect that the BWRX-300 UK GSE values would be updated using site-specific values, derived through analysis that considers duration, in a future version of the safety case.

107. For those BWRX-300 UK GSE values that have been derived on a quantitative basis, the RP has not directly demonstrated within this GDA how the chosen values would bound a potential GB site and the detailed methodologies for derivation of the hazards has not been available. I have compared the BWRX-300 UK GSE values to those of existing licensees and previous GDA GSEs (refs. [96], [99]) and I have found these comparable. I consider that the BWRX-300 UK GSE values are therefore likely to bound the EN-6 sites for seismic hazards and those ten external hazards within the scope of GDA that have been quantitatively defined, with the potential exception of high air temperature.

108. Noting that further work is required on the hazard duration, I am satisfied that the RP has met the intent of SAP EHA.3 – design basis events (ref. [13]), for those BWRX-300 UK GSE values that have been derived on a quantitative basis during this GDA. For the external hazards within scope of this GDA, and for specific external hazards where reassurance has been provided during GDA (seismic hazards and aircraft impact), I consider that the BWRX-300 UK GSE values are likely to bound a future EN-6 site.

109. I have considered some specific external hazards in more detail where:

- The GSE values are not bounded by the SPD parameters:
    - **High air temperature** - BWRX-300 UK GSE values exceed the SPD parameters, for some SSCs within the Power Block. High air temperature is important for the design of heating, ventilation and air-conditioning (HVAC) systems. In previous GDAs it has been difficult for RPs to design these systems to meet the requirements of the high air temperature GSE value (ref. [98]) and this led to the requirement for design changes late in the process, including in the site-specific stage. High air temperature is discussed further in section 4.3.4.2.
    -
- Site-specific external hazards where some reassurance can be provided during GDA, focusing on those that have the greatest potential impact on the civil engineering design:
    - **Seismic** - Additional information is included in the civil engineering sections of the PSR, and supporting references. This demonstrates that the range of ground conditions considered for seismic hazards in the BWRX-300 SPD is likely to bound a potential site in GB. Seismic hazards also impact a substantial part of the civil engineering design. Seismic hazards are discussed further in section 4.3.4.1.
    - **Aircraft impact** - Additional information is included in the civil engineering and security sections of the PSR, and supporting references, in relation to malicious aircraft impact. Aircraft impact is an important hazard to be considered early in the design phase as it impacts a substantial part of the civil engineering design. Aircraft impact hazards are discussed further in section 4.3.4.3.

110. I have not provided detailed commentary in this report on high humidity, high water temperature, low water temperature and lightning as no SPD parameter is available within this GDA. A brief summary is provided below:

- **High humidity** - For the BWRX-300 UK GSE, the RP has defined a maximum relative humidity value of 100%. SPD values are based on wet bulb temperature exceedance values so are not directly comparable with the BWRX-300 UK GSE values. I consider the maximum relative humidity value of 100% to be conservative for the purposes of GDA, and this is consistent with previous GDAs (ref. [99]).

- **High water temperature** - For the BWRX-300 UK GSE, the RP has defined a high water temperature of 30 ˚C with a climate change adjustment of 2.2 ˚C. No duration has been defined within GDA. The RP has not defined an SPD parameter within GDA as heat sink design is site-specific and out of scope for GDA Step 2. The high water temperature value proposed for the BWRX-300 UK GSE is consistent with/bounding of previous GDAs, including the UK ABWR GDA (refs. [96], [99]) and recent new build projects (refs. [100], [101]). I therefore consider this to be appropriate for the purposes of GDA.

- **Low water temperature** - For the BWRX-300 UK GSE, the RP has defined a low water temperature of -1.9 ˚C. No duration has been defined within GDA. The RP has conservatively assumed that the climate change adjustment is zero. The RP has not defined an SPD parameter within GDA as heat sink design is site-specific and out of scope for GDA Step 2. The low water temperature value proposed for the BWRX-300 UK GSE, including the assumption that the climate change adjustment is zero, is consistent with/bounding of previous GDAs, including the UK ABWR GDA (refs. [96], [99]). I therefore consider this to be appropriate for the purposes of GDA.

- **Lightning** - For the BWRX-300 UK GSE, the RP has defined a peak lightning strike current of 300 kA, a lightning flash density of 1.4 flashes/km^2/year and an average of 15 days of thunder per year. The RP has not defined an SPD parameter within GDA. The values proposed for the lightning hazard in the BWRX-300 UK GSE are consistent with/bounding of previous GDAs, including the UK ABWR GDA (refs. [96], [99]) and recent new build projects (refs. [100], [101]). I am content with the RP's commitment to derive a climate change adjustment for lightning beyond Step 2, in a future version of the safety case (see FAP PSR 15.8-149). I therefore consider the RP's characterisation of the lightning hazard to be appropriate for the purposes of GDA.

111. I have not provided detailed commentary in this report on low air temperature, strong winds, tornadoes, extreme rain and extreme snow as the SPD parameters bound the BWRX-300 UK GSE (with the potential exception of low air temperature for longer duration events), even with different return periods and durations. A brief summary is provided below:

- **Low air temperature** - For the BWRX-300 UK GSE, the RP has defined a low air temperature of -22 ˚C for coastal locations and -38.4 ˚C for inland locations. No duration has been defined within GDA. The RP has conservatively assumed that the climate change adjustment is zero. The

SPD low air temperature is -40 °C for less than two hours, and -32.5 °C for 1 day. The SPD low air temperature value for less than two hours bounds BWRX-300 UK GSE values. Durations would be needed for the BWRX-300 UK GSE low air temperature value to compare with SPD parameters, particularly for longer duration events. The low air temperature values proposed for the BWRX-300 UK GSE, including the assumption that the climate change adjustment is zero, is consistent with previous GDAs, including the UK ABWR GDA (refs. [96], [99]). I therefore consider this to be appropriate for the purposes of GDA. This is a topic that will require further analysis as part of a future Step 3 GDA or future site-specific activities, to ensure that the methodologies for deriving the hazard are appropriate and to ensure that the BWRX-300 SPD can withstand the BWRX-300 UK GSE for longer duration events.

- **Strong winds** - For the BWRX-300 UK GSE, the RP has defined a mean wind velocity of 43.1 m/s with an additional +2 m/s climate change adjustment. The PSR indicates that this is a 10-minute mean wind velocity (ref. [3]). Within the SPD, a severe wind of 71.5 m/s for a 3-second gust for a return period of 3,000 years and an extreme wind of 89.4 m/s has been derived. The BWRX-300 UK GSE mean wind velocity bounds the UK ABWR GDA GSE value (ref. [96]). There appears to be significant margin between the BWRX-300 UK GSE value and the BWRX-300 SPD, even with different return periods and durations. I therefore consider this to be appropriate for the purposes of GDA. For strong winds, other durations may be of interest (for example, 3-second gust). This is a topic that will require further analysis as part of a future Step 3 GDA or future site-specific activities, to ensure that the methodologies for deriving the hazard are appropriate and to ensure that the BWRX-300 SPD can withstand the BWRX-300 UK GSE values.

- **Tornadoes** - For the BWRX-300 UK GSE, the RP has defined a maximum tornado wind speed 89.4 m/s, a tornado maximum pressure drop 63 mbar, tornado pressure drop rate 25 mbar/s and provided details of tornado missiles. The RP has not defined a climate change adjustment within the BWRX-300 UK GSE. For the SPD, the RP has defined a maximum wind speed of 103 m/s, a tornado maximum pressure drop of 83 mbar and a tornado pressure drop rate of 37 mbar/s. Details of tornado missiles are also provided for the SPD. The BWRX-300 UK GSE values proposed for the tornado hazard are consistent with previous GDAs (ref. [99]), and there is margin between the BWRX-300 UK GSE value and the BWRX-300 SPD. I therefore consider this to be appropriate for the purposes of GDA. I am content with the RP's commitment to derive a climate change adjustment for tornadoes beyond Step 2, in a future version of the safety case (see FAP PSR 15.8-149).

- **Extreme rain** - For the BWRX-300 UK GSE, the RP has defined an extreme rainfall value of 210.3 mm in 1 hour (including a 29% climate change adjustment) and 400 mm in 24 hours. Within the SPD, plant structures are designed to accommodate a maximum rainfall rate of 493 mm/hr, and maximum short-term rain fall rate of 157 mm in 5 minutes. The 1 hour and 24 hour extreme rainfall values proposed for the BWRX-300 UK GSE are consistent with previous GDAs, including the UK ABWR GDA (refs. [96], [99]) and there is significant margin between the BWRX-300 UK GSE value and the BWRX-300 SPD. I therefore consider this to be appropriate for the purposes of GDA. For rainfall, other durations may be of interest. This is a topic that will require further analysis as part of a future Step 3 GDA or future site-specific activities, to ensure that the methodologies for deriving the hazard are appropriate.

- **Extreme snow** - For the BWRX-300 UK GSE, the RP has defined a snow load value of 1.5 kN/m^2. The RP has not defined a climate change adjustment within the BWRX-300 UK GSE. The SPD snow load value is a maximum ground snow load of 2.5 kN/m^2 for normal winter precipitation events and 5 kN/m^2 for extreme winter precipitation events. The snow loading value proposed for the BWRX-300 UK GSE is consistent with previous GDAs, including the UK ABWR GDA (refs. [96], [99]) and there is significant margin between the BWRX-300 UK GSE value and the BWRX-300 SPD. I therefore consider this to be appropriate for the purposes of GDA. I am content with the RP's commitment to derive a climate change adjustment for extreme snow beyond Step 2, in a future version of the safety case (see FAP PSR 15.8-149).

- **Fog** - The RP has not quantitatively defined the fog hazard for the BWRX-300 UK GSE. I do not consider this to be a fundamental shortfall, as the fog hazard has not been quantitatively defined in previous GDAs, including the UK ABWR GDA (refs. [96], [99]). I am content that this could be addressed beyond Step 2, in a future version of the safety case.

4.3.4.1. Seismic hazards

112. For the BWRX-300 UK GSE Design Basis Earthquake (DBE), the horizontal generic design response spectra (GDRS) are anchored at 0.3g peak ground acceleration (PGA) (refs. [3], [4], [8]). Vertical GDRS are developed by multiplying horizontal GDRS by a frequency-dependent vertical-to-horizontal (V/H) spectral ratio (ref. [8]). I have compared the RP's proposed GSE value for earthquake ground motion with previous GDAs (for example, refs. [96], [99]). I judge that the RP's approach to defining the PGA is bounding of/equal to previous GDAs (for example, refs. [96], [99]). I am satisfied that the RP has met the intention of SAP EHA.3 – design basis events and SAP EHA.4 – frequency of initiating event (ref. [13]), given the current maturity of the design.

113. The RP has identified that further work is required to confirm the UK DBE for SSCs seismically categorised as RW, and whether the current approach of one half of the site-specific DBE is appropriate (ref. [8]). The Seismic Category RW is adopted for the Radioactive Waste Building in the BWRX-300 design, and this is based on the definition of RW-IIa in US NRC Regulatory Guide 1.143 (ref. [79]). This is captured in FAP PSR 15.8-137 to be addressed at a future site-specific stage (refs. [8], [97]). The RP did not provide any further analysis within this GDA. I have therefore not been able to assess this at Step 2.

114. For the BWRX-300 standard plant design, the RP has developed four GDRS for both horizontal and vertical motion at medium, hard, firm and increased hard sites (refs. [4], [102], [103]), which has been compared against European Utility Requirements (EUR) soft, medium, hard and very hard spectra (ref. [103]). With respect to the definition of the DBE, for new build the use of a standardised spectrum constitutes RGP (ref. [57], Annex 1) and EUR is cited as an example of a commonly used standardised response spectral shape (ref. [57], Annex 1). The envelope of the four BWRX-300 spectra, bounds all EUR spectra up to 100 Hz. When the BWRX-300 increased hard spectra is excluded, the BWRX-300 spectra bound the EUR spectra up to 70 Hz. I judge that the RP’s approach demonstrates that the RP is considering a range of potential ground conditions for future deployment of the BWRX-300 design, that would likely bound a future GB site.

115. The RP has also compared the BWRX-300 range of shear velocity values against the EUR ground properties and the hardest and softest EN-6 sites in GB (Wylfa Newydd and Bradwell respectively) (refs. [102], [103]). The RP considers that the BWRX-300 hard profile is broadly comparable to Wylfa Newydd, and that one of the soft profiles is broadly comparable to the Bradwell site (ref. [103]). I am satisfied that the RP has demonstrated that the range of ground profiles used for the BWRX-300 SPD is likely to bound a potential site in GB.

116. The RP has developed a seismic categorisation approach for the BWRX-300 design (ref. [4]). The safety classification and seismic categorisation of civil structures is discussed further in the civil engineering assessment report (ref. [77]).

117. The application of the seismic categorisation approach to SSCs within buildings has been covered by the engineering topics:

- The ONR electrical engineering assessor has considered the RP’s approach to the proposed seismic resilience of the safety classified electrical systems (ref. [104]).

- The ONR C&I assessor has considered the RP's approach to the proposed resilience of C&I systems within the Reactor Building to foreseeable hazards such as seismic hazards (ref. [105]).

118. The RP has not defined an Operating Basis Earthquake (OBE) as part of the BWRX-300 UK GSE during this two-step GDA. The RP is considering that the OBE could be in the range of 0.05-0.1g, based on EUR (ref. [106]). The RP has set the OBE at one third of the DBE for design purposes in the BWRX-300 standard plant design (ref. [106]), to be suitably bounding until an OBE is defined for the UK. Given the current maturity of the design, I am satisfied that the RP understands the expectations of SAP EHA.9 – earthquakes (ref. [57]), in relation to defining an OBE. The RP has stated that work to define the OBE will form part of site-specific assessment of the seismic hazard (ref. [8]), which is captured in FAP PSR 15.8-144. Based on the information in the PSR and the information provided in response to RQ-02063 (ref. [106]), I am satisfied that this can be addressed as part of a future Step 3 GDA or future site-specific activities.

119. The RP has acknowledged that further work would be required in a future site-specific safety case, through FAPs PSR 15.8-143 and PSR 15.8-144. Based on the information provided within the GDA (refs. [4], [8], [102], [103], [106]), I am satisfied that the BWRX-300 UK GSE for seismic hazards is likely to bound a future GB site.

120. The ONR PSA assessor has considered the RP's high wind PSA and seismic PSA as part of their assessment (ref. [93]), acknowledging that this will have to be updated at a future site-specific stage. The PSA assessor considered the internal events Level 1 PSA in their assessment and the findings are applicable to the external hazards PSA (ref. [93]). The PSA assessor found the seismic PSA conclusions to be logical and thorough and was satisfied that the results of the seismic PSA met their expectations for Step 2 of GDA (ref. [93]).

4.3.4.2. High air temperature

121. For high air temperature, the RP has defined a BWRX-300 UK GSE value of 40.2 ˚C for a coastal location and 45.4 ˚C for an inland location, with an additional climate change adjustment of 5.4 ˚C (ref. [8]). No duration has been defined within GDA. The RP has defined the high air temperature hazard for the GSE using Eurocode 1991-1-5 (ref. [107]) and the UK National Annex (ref. [108]), using maximum UK temperatures for coastal and inland locations. Eurocode represents RGP, and in the absence of site-specific temperature data, I judge the use of this code to meet the expectations of SAP EHA.2 - data sources (ref. [13]), for use of best available relevant data.

122. The RP has used the UKCP18 RCP 6.0 probabilistic projections at the 90th percentile for the year 2099 to derive the climate change adjustment (ref. [8]). I judge this approach to be consistent with ONR's expectations in SAP

EHA.11 – weather conditions (ref. [13]) and the Position Statement on the use of UKCP18 (ref. [60]).

123. I note that no durations have been defined for the BWRX-300 UK GSE values, or the SPD parameters. I raised RQ-01853 (ref. [109]) because the BWRX-300 UK GSE values exceed the SPD parameters, for some SSCs within the Power Block. It is of note however, that the BWRX-300 UK GSE values bound values adopted on current UK nuclear new build sites.

124. I consider that the high air temperature value is important for the design of HVAC systems, and this has been recognised as a challenge on previous GDAs (ref. [98]). Chapter 15.8 of the PSR (ref. [8]) provides the RP's protection strategy for high air temperature. The PSR (ref. [8]) states that the design of the HVAC system is intended to be customisable to accommodate customer requirements for different site-specific external air temperature and humidity ranges. The RP anticipates that the heating and cooling functionality of the HVAC design for a UK BWRX-300 deployment would be modified according to the site-specific envelopes of these parameters (ref. [8]).

125. I judge that the BWRX-300 UK GSE high air temperature values are not a fundamental shortfall as FAP PSR 15.8-142 (ref. [8]) specifically covers the future demonstration that the BWRX-300 UK GSE values are bounded by the associated SPD parameters. This is a topic that will require further analysis as part of a future Step 3 GDA or future site-specific activities, to ensure that the BWRX-300 SPD can withstand the BWRX-300 UK GSE values.

4.3.4.3. Aircraft impact

4.3.4.3.1. Accidental aircraft impact

126. Within the BWRX-300 design, the Reactor Building acts as the primary hazard shield against external hazards. The Reactor Building external walls and roof structure are designed so that in the event of aircraft impact, there is no perforation of the Reactor Building and the integrity of the Reactor Building is maintained (refs. [8], [110]). Safety Class 1 components within the Reactor Building are assumed to remain intact and maintain their intended functions following the impact of a large commercial aircraft (ref. [8]). Further information on the BWRX-300 aircraft impact protection strategy for other buildings in the Power Block is discussed in section 4.3.3.3.2 and in the civil engineering report (ref. [77]). The RP has identified that further work is required to analyse the response of the plant to accidental aircraft impact, through FAP PSR 15.8-147 and in the safety case manual specification (ref. [97]). I do not consider this to be a fundamental shortfall that would prevent the BWRX-300 design from being licensed for construction and operation in GB.

127. The RP has not defined frequencies for accidental aircraft impact within the scope of GDA (ref. [49]) and I have therefore not been able to undertake an assessment against SAP EHA.8 – aircraft crash (ref. [13]). The RP notes that for each discrete class of aircraft (for example light civilian aircraft, large transport), it is envisaged that accidental aircraft impact would be considered as beyond design basis due to low frequency (ref. [8]). I am satisfied that the RP's position is consistent with other GDAs, and I am content that the RP has identified forward work to address this in a future version of the safety case, through FAP PSR 15.8-147.

4.3.4.3.2. Malicious aircraft impact

128. The RP has considered large aircraft impact for the Reactor Building, and small aircraft impact for the Reactor Building, Turbine Building, Radioactive Waste Building, Service Building and Control Building (ref. [111]). For large aircraft impact, the SSCs located in the Reactor Building maintain their intended functions and SSCs in the other buildings are assumed failed (ref. [111]). For small aircraft impact into the Turbine Building, Radioactive Waste Building, Service Building and Control Building, the SSCs located in the affected building are assumed to fail. The SSCs in the other buildings are credited to maintain fuel cooling (ref. [111]). The ONR civil engineering assessor (ref. [77]) has highlighted that the RP's protection strategy has not fully considered the MCR, which is located in the Control Building and would require further analysis as part of a future Step 3 GDA or site-specific activities. Taking cognisance of the civil engineering assessment (ref. [77]), I am satisfied that the protection strategy for malicious aircraft impact can be developed further as the design matures.

129. The RP has developed proxy values for malicious aircraft impact to progress an international standard design (ref. [112]). These proxy values are derived using information from Nuclear Energy Institute guidance (ref. [113]) and IAEA Safety Report No. 87 (ref. [114]). Using these methodologies, the RP has used a forcing function to represent a reference aircraft. A proxy standard aircraft type, fuel, velocity or cargo configuration has not been established (ref. [112]).

130. In response to RQ-02003 (ref. [112]), the RP provided a copy of its aircraft impact assessment methodology and how US and Canadian regulatory safety requirements for aircraft impact have been taken into account in the BWRX-300 design. Whilst the RP has not fully considered UK regulatory safety requirements for malicious aircraft impact within this GDA, the RP has demonstrated its strategy for meeting regulatory expectations in Canada and the US. The ONR civil engineering assessor has highlighted that an increase in wall thickness may be required for some structures in the Power Block to meet UK regulatory expectations for malicious aircraft impact (ref. [77]). The ONR civil engineering assessor (ref. [77]) does not consider this to be a fundamental shortfall that would prevent the BWRX-300 design from being licensed for construction and operation in GB.

131. Whilst the RP has not yet undertaken a full assessment of the malicious aircraft hazard definition and impacts on the BWRX-300 design, the information shared in response to RQs 01826, 01897, 02003 and 02314 (refs. [110], [111], [112], [115]), demonstrates that the RP has appropriate awareness of this issue and has been developing its design requirements and safety case philosophy. I do not consider this to be a fundamental shortfall that would prevent the BWRX-300 design from being licensed for construction and operation in GB. For external hazards and civil engineering, malicious aircraft impact would be a priority topic to be addressed at a future stage. This is because aircraft crash can have potentially widespread effects, challenging multiple safety systems in multiple locations simultaneously and therefore needs to be considered fully before the start of construction.

4.3.5. Hazard combinations

132. Combined hazards can pose significant challenge to nuclear reactor designs. During the UK ABWR GDA, this was a significant focus, recognising learning from the Fukushima nuclear accident. I sampled the RP’s consideration of combined hazards during Step 2 to assure myself that a suitable approach to identification, screening and characterisation of combined hazards has been developed and is informing the design from an early stage.

133. The RP acknowledged that identification of hazard combinations has not yet been undertaken at this stage, but would be addressed as safety case and design development progresses. Within this GDA, the majority of the RP’s assessment of hazard combinations is presented within the PSA (ref. [86]). I am satisfied that the RP has captured several forward actions which will need to be addressed in a future version of the safety case (ref. [86]). FAP items for combined hazards are captured in the combined hazards topic report (ref. [86]), and appropriate PSR chapters (refs. [7], [8], [32], [35]).

134. The RP submitted a topic report for combined hazards (ref. [86]), which provides a high-level methodology for the BWRX-300 combined hazards identification and assessment process. The RP has not identified any hazard combinations within this report, as this was out of the RP’s scope for this GDA (ref. [49]). The RP identified the key combinations to be as two or more internal hazards; combinations of external and internal hazards; and combinations of two or more external hazards. I consider this to be aligned with international guidance (refs. [53], [67], [69], [70], [73]) and ONR guidance (ref. [57]). The RP has identified FAP PSR 15.8-151 to incorporate OPEX arising from external hazards events, including Fukushima (ref. [8]). I am satisfied that the RP has demonstrated its intention to address this in a future version of the safety case.

135. I concur with the internal hazards assessor that a meaningful assessment of combined hazards cannot be carried out at Step 2 (ref. [116]) against SAPs EHA.1 – identification and characterisation and EHA.6 – analysis (ref. [13]). I

do not consider this to be a fundamental shortfall and I am content with the RP's commitment to address this beyond GDA Step 2, in a future version of the safety case.

4.3.6. Consideration of climate change in the GSE

136. The RP has used RCP 6.0 from UKCP18 at the 90th percentile to derive climate change adjustments for the BWRX-300 GDA, for relevant external hazards. For some hazards, RCP 6.0 data is not available and alternative RCPs have been used (either RCP 4.5 (high water temperature only) or RCP 8.5). Where parameters are not covered by UKCP18, the RP states that best available data has been used.

137. Previous GDAs have provided evidence that the upper percentiles of RCP 6.0 meet ONR's expectations relating to specific variables such as high air temperature (refs. [99], [117]). It is of note however, that for certain variables (such as sea level) no data is provided for RCP 6.0, as the results within UKCP18 were shown to be indistinguishable from RCP 4.5. I do not consider the use of RCP 4.5 for the high water temperature hazard to be a fundamental shortfall, at this stage of the GDA, as data from RCP 6.0 is not available for this hazard. Moreover, further site-specific analysis of cliff-edges and beyond design basis analysis has been identified in the FAP (PSR 15.8-143).

138. For hazards such as rainfall, UKCP18 provides a generic UK allowance as well as regional allowances. For rainfall, the RP has adopted the UK generic value for the GSE. It is of note however, that many of the regional allowances are higher. I raised RQ-01854 on this topic (ref. [118]). The RP's response demonstrates that the RP has appropriate awareness of the issue. I do not consider this a fundamental shortfall as flooding mitigation from rainfall features site-specific drainage design analysis which will be addressed through FAPs PSR 15.8-142, 15.8-144, 15.8-145 and 15.8-152.

139. Overall, I consider that the RP's approach to climate change is aligned with previous GDAs (for example, refs. [99], [117]) and I am satisfied that the RP has met the intention of SAP EHA.2 – data sources and SAP EHA.11 – weather conditions (ref. [13]). Further work would be required at a future site-specific stage, when site-specific hazard values and durations have been defined.

4.3.7. Standard plant design (SPD) parameters

140. I have examined how the BWRX-300 UK GSE values compare with the BWRX-300 SPD parameters. This is summarised in Chapter 15.8 of the PSR (refs. [8], [119]) and Appendix 3 of this assessment report. The BWRX-300 SPD parameters are intended to be applicable to the BWRX-300 design in any country of deployment and will be used to develop individual system requirements.

141. I note that it is not possible to make direct comparisons between the BWRX-300 UK GSE values and BWRX-300 SPD parameters for all external hazards, as durations are not yet defined and different return periods have been used. However, for most external hazards within the scope of GDA, the BWRX-300 SPD parameters are bounding of the BWRX-300 UK GSE values. I note that the values adopted are consistent with those detailed within previous GDAs and are therefore likely to be bounding of GB site-specific conditions. I do not, therefore, consider this a fundamental shortfall but it is something that will require further analysis in subsequent stages.

142. I note that FAP PSR 15.8-142 (ref. [8]) specifically covers the future demonstration that the BWRX-300 UK GSE values are bounded by the associated SPD parameters. I consider that this could be addressed during the production of a future safety case, and therefore I do not consider this to be a fundamental shortfall that would prevent the BWRX-300 design from being licensed for construction and operation in GB. I would expect the focus of future work to be those external hazards where the SPD parameters do not bound the UK GSE (such as high air temperature), or where there is limited margin between the UK GSE and SPD parameters.

4.3.8. Consideration of cliff-edge effects and beyond design basis

143. The RP has considered categories of plant states (ref. [80]), including design extension conditions, in line with IAEA guidance (refs. [62], [64]). This includes beyond design basis accidents (BDBA) and design extension conditions (DEC).

144. There is some consideration of cliff-edge effects in the PSA (refs. [7], [92]), in particular for seismic hazards, and some qualitative discussion of margins and cliff-edge effects for those hazards screened into GDA in Chapter 15.8 of the PSR (ref. [8]). Where sensitivity studies have been undertaken within the PSA, for example for seismic hazards, the RP has shown that the BWRX-300 can still safely shutdown in response to earthquakes beyond the DBE (ref. [92]).

145. For seismic hazards, the RP has used an additional horizontal GDRS, anchored at 0.5g, to envelope hard rock high frequency sites in the US (ref. [103]). This is higher than peak ground accelerations typically considered in the UK, and is an example of how the BWRX-300 design has incorporated margin beyond the DBE of 0.3g. This provides assurance of the overall resilience of the civil engineering design against seismic hazards, including beyond the design basis. The RP has identified FAP PSR 15.8-143 to undertake future analysis at a site-specific stage to determine the return frequency at which fundamental safety functions will be lost and to demonstrate the absence of cliff-edge effects (ref. [8]).

146. I do not consider that I can perform a meaningful assessment against SAP EHA.7 – cliff edge effects or EHA.18 – beyond design basis events (ref. [13]), given the current maturity of the work on beyond design basis margins

and cliff-edge effects. Nonetheless, I have identified examples, such as for seismic hazards, where there is additional resilience incorporated in the BWRX-300 design, beyond the design basis, which provides confidence in the design. I am satisfied that the RP has captured the requirement for further work in the FAPs (PSR 15.8-142 and PSR 15.8-143) and that this could be addressed at a future site-specific stage.

4.3.9. Leveraging UK ABWR GDA

147. I have considered ONR's previous Step 4 GDA external hazards assessment of the UK ABWR design (ref. [96]) and ONR's external hazards assessments of previous GDAs (refs. [99], [117]). For most external hazards, a direct comparison between the BWRX-300 UK GSE values and the UK ABWR GDA GSE values is not possible, because hazards and climate change adjustments have been derived differently in the two GDAs (for example, different durations, different climate scenarios, different end of lifetime dates). Where comparison is possible, I note that the BWRX-300 UK GSE values are generally equal to, or greater than the UK ABWR GSE values. This indicates that the values proposed in the BWRX-300 UK GSE are suitably conservative for the purposes of GDA.

148. ONR's previous Step 4 GDA external hazards assessment of the UK ABWR design identified five assessment findings, which are summarised in Appendix 4 of this assessment report, along with commentary as to how these have been addressed in the BWRX-300 GDA:

- **AF-ABWR-EH-01** - Site-specific assessment to determine the design basis tornado wind speed.
- **AF-ABWR-EH-02** - Consideration of sources of naturally-occurring electromagnetic interference from extreme space weather events including geomagnetic storms, solar radiation storms, and radio blackouts.
- **AF-ABWR-EH-03** - Review of hazard combinations at the site-specific stage to ensure that all reasonably foreseeable combinations of hazards for a specific site have been included in the analysis.
- **AF-ABWR-EH-04** - A future licensee shall consider and implement adequate water sealing and/or elevation of relevant buildings based on site-specific evaluation of external flooding beyond the design basis.
- **AF-ABWR-EH-05** - A future licensee shall consider whether or not the site-specific seismic analysis demonstrates that the generic site envelope's seismic hazard definitions are bounding.

149. The RP has provided some evidence to address AF-ABWR-EH-01 and AF-ABWR-EH-02 within this two-step GDA. The other three UK ABWR external

hazards assessment findings are site-specific, so I would not expect these to have been addressed within this two-step GDA.

150. In relation to AF-ABWR-EH-01, the RP has defined a maximum tornado wind speed, tornado maximum pressure drop, tornado pressure drop rate in the BWRX-300 UK GSE and BWRX-300 SPD (refs. [3], [8]). Tornado missile dimensions, mass and velocity are also included within the BWRX-300 UK GSE and BWRX-300 SPD. I am satisfied that the RP has taken cognisance of this assessment finding, and has demonstrated appropriate progress to address AF-ABWR-EH-01 and characterise this hazard within Step 2 of this GDA. Appendix 3, Appendix 4 and Section 4.3.3 of this assessment report provide more information on this topic.

151. In relation to AF-ABWR-EH-02, electromagnetic interference and space weather are both considered as site-specific hazards by the RP, with some reassurance provided during GDA (ref. [8]). The RP has stated that the passive nature of the BWRX-300 design reduces the potential impact of geomagnetically induced current (GIC) events, as the design does not require electrical power to actuate safety functions during a LOOP event (ref. [120]). Within this GDA, the RP has outlined the BWRX-300 design features that reduce the risk from GIC events (ref. [120]). The RP has also evaluated the effects of GIC to meet CNSC expectations for electrical power systems (ref. [121]). I am satisfied that the RP has demonstrated appropriate progress to address AF-ABWR-EH-02 within Step 2 of this GDA, and has demonstrated how the BWRX-300 design may reduce the potential impact of GIC events during a LOOP event. Future work is tracked under FAP items PSR 15.8-140, 15.8-143, 15.8-144 and 15.8-146 (ref. [8]).

152. I am satisfied that the RP can address the outstanding UK ABWR external hazard assessment findings in a future version of the safety case at the site-specific stage.

4.3.10. Plant layout to support resilience against external hazards

153. As part of my assessment, I have considered how the BWRX-300 design and plant layout minimises the effects of external hazards.

154. The RP has five defence lines, as part of its defence-in-depth approach (ref. [81]). Within the scope of this GDA, the RP has identified external hazards that may impact the BWRX-300 design, but more detailed analysis of these hazards is not complete due to the current maturity of the design (see also sections 4.3.2-4.3.8). Whilst this should be captured in a future version of the safety case, I do not consider that this is a fundamental shortfall that would prevent the BWRX-300 design from being licensed for construction and operation in GB.

155. Within the BWRX-300 design, there are some novel considerations from an external hazards perspective as the Reactor Building is partially below grade. Some of these may have benefits from an external hazards

perspective, whilst some may present novel challenges. All Safety Class 1 SSCs are located within the Reactor Building, which provides the principal means of protection against multiple external hazards. These are discussed in the following paragraphs, 156-159.

156. The Reactor Building shields the containment vessel structure and safety equipment from external hazards. The Reactor Building is a Seismic Category 1A structure. The RP highlights that seismic demands on the Reactor Building are reduced, as the majority of the Reactor Building is below grade (ref. [122]). With the majority of the Reactor Building below grade, the target area for external hazards such as aircraft impact and man-made external hazards such as explosions is reduced (ref. [122]). I judge that the RP has provided examples of how external hazards considerations have been incorporated into the decisions to embed the Reactor Building below grade which meet the intent of SAP ELO.4 – minimisation of the effects of incidents (ref. [13]).

157. The maximum flood level and local intense precipitation levels are claimed not to exceed plant grade for the BWRX-300 design (ref. [8]). All Reactor Building exterior openings and penetrations are above ground level. Currently, the BWRX-300 design has no external flooding protection features and no dewatering features (ref. [8]). A requirement has however, been identified to develop site-specific flood protection measures that ensure suitable water tightness flood protection measures. Given the limited evidence available and site-specific nature of this topic, I do not consider that a meaningful assessment of external flooding can be carried out at Step 2 against SAP EHA.12 – flooding (ref. [13]). I am however, content with the RP’s commitment to address this beyond GDA Step 2, in a future version of the safety case (FAPs PSR 15.8-135, 15.8-136, 15.8-144, 15.8-145).

158. The more compact layout of the BWRX-300, compared to larger gigawatt reactors, and the location of the majority of the Reactor Building below grade, reduces the overall target area for aircraft impact (both accidental and malicious) and missiles. The Reactor Building and Control Building are qualified against design basis tornado missiles and the Reactor Building is designed to withstand large aircraft impact (refs. [8], [110], [111]). The RP clarified that the Turbine Building is not qualified against design basis tornado missiles (ref. [123]). As the Turbine Building structures are Seismic Category Non-Seismic and Seismic Category 2 (ref. [123]), I do not consider this to be a fundamental shortfall against the RP’s design specification for missiles. Future work is tracked under FAP items PSR 15.7-72, 15.8-135 and 9B-313 (refs. [5], [8]).

159. Chapter 15.8 of the PSR (ref. [8]) states that there are no BWRX-300 safety classified SSCs directly exposed to ambient environmental conditions (ref. [8]). HVAC systems are claimed to maintain the environment in the Power Block buildings within appropriate parameters, for those SSCs that are sensitive to temperature, even in the event of high external air temperatures

(ref. [8]). In addition, the RP states that the isolation condenser system provides passive heat removal against those external hazards which could result in loss of heat sink or LOOP (ref. [8]). The RP states that non-safety classified SSCs directly exposed to ambient environmental conditions and required to maintain their function, are assumed to be designed for 40 ˚C (ref. [8]). With the majority of the Reactor Building below grade, I consider that this could provide benefits for some meteorological hazards as safety classified SSCs are not directly exposed to ambient environmental conditions. For external hazards, the impacts of high air temperature on the BWRX-300 design would be a priority topic for further discussion at a future stage. This is because in previous GDAs, it has been challenging for RPs to design HVAC systems to meet the requirements of the high air temperature value (ref. [98]), which has led to design changes in both GDA and site-specific stages (see section 4.3.3.2 for further information).

160. Section 3.3 of Appendix 1 of (ref. [4]) outlines how protection against external hazards has been incorporated into the BWRX-300 design. I am satisfied that at this stage in the design, the RP has demonstrated that it has considered the potential impacts of external hazards on the BWRX-300 design in accordance with the expectations of SAP ELO.4 – minimisation of the effects of incidents (ref. [13]). This is discussed further in the civil engineering report (ref. [77]).

4.3.11. Future ALARP demonstration

161. Within this GDA, the RP has developed a strategy for how risks can be shown to be ALARP at a future site-specific stage (refs. [8], [9]). I judge this to be appropriate for a Step 2 GDA.

162. The RP has identified relevant claims and arguments to support a future ALARP demonstration for external hazards (ref. [8]). The arguments have not all been addressed in the PSR within Step 2 of the GDA, and the supporting evidence is not available at this stage of GDA, which is consistent with the agreed scope of the GDA. I do not consider this to be a fundamental shortfall given the current maturity of the design, and the agreed scope of this GDA (ref. [49]).

163. It was not within the scope of this GDA for the RP to provide a full demonstration that the risks to operators and the public from the effects of external hazards on the BWRX-300 are ALARP. However, the RP has identified, in the PSR (refs. [8], [9]), how a future ALARP demonstration might be developed within. If the approach outlined in the PSR (refs. [8], [9]) is applied as part of a future UK project, I consider that it should be possible to demonstrate that the BWRX-300 design could reduce risks ALARP.

5. Conclusions

164. This report presents the Step 2 external hazards assessment for the GDA of the BWRX-300 design. The focus of my assessment in this step was towards the fundamental adequacy of the design and safety case. I have assessed the SSSE chapters and relevant supporting documentation provided by the RP to form my judgements. I targeted my assessment, in accordance with my assessment plan (ref. [17]), at the content of most relevance to external hazards against the expectations of ONR's SAPs, TAGs and other guidance which ONR regards as relevant good practice.

165. Based upon my assessment, I have concluded the following:

- The design and external hazards aspects of the safety case presented at Step 2 are at an early stage of design maturity. Further development of the design and safety case is required, at a future stage, including site-specific and deterministic analysis to meet UK regulatory expectations. For external hazards, this is particularly important as a future licensee will need to demonstrate the suitability of a site for deployment of the BWRX-300 design. I am satisfied that the RP has identified the main areas for further development, in relation to external hazards, as part of its FAP (ref. [8]), and that these could be resolved as part of a future Step 3 GDA or future site-specific activities.

- The RP has provided its approach to assessment of external hazards, which will form the basis for a future external hazards safety case. Detailed methodologies, including those for individual hazards, were not available during Step 2. I am satisfied that appropriate external hazards have been considered for hazard identification and screening during Step 2 of this GDA. In relation to the external hazards assessment for the BWRX-300, I am satisfied that the RP has identified areas for further development, as part of its FAP (ref. [8]), and that these could be resolved as part of a future Step 3 GDA or future site-specific activities.

- The RP has defined a UK GSE for the BWRX-300 design. I have compared the GSE values proposed by the RP, to those of existing licensees and previous GDA GSEs and I have found these comparable. The BWRX-300 UK GSE values therefore appear to bound the sites set out in the National Policy Statement for nuclear power generation (EN-6) for those eleven external hazards within the scope of GDA. Overall, I consider that the RP's GSE for the external hazards within scope of this GDA, and for specific external hazards where reassurance has been provided during GDA (seismic and aircraft impact), is appropriate for a two-step GDA.

- For those external hazards where a BWRX-300 UK GSE value has been defined, I am satisfied that they are bounded by the SPD parameters, with the exception of high air temperature. I judge that this is not a fundamental shortfall, and I am content that this could be resolved as part of a future Step 3 GDA or future site-specific activities. I am satisfied that the RP has identified areas for further development, as part of its FAP (ref. [8]), including the demonstration that the BWRX-300 UK GSE values are bounded by the associated SPD parameters, to be addressed as part of a future Step 3 GDA or future site-specific activities.

- The RP has considered climate change for relevant external hazards that may be affected by it. I am satisfied that the RP's approach to climate change is aligned with previous GDAs and takes account of the most recent UK Climate Projections (UKCP).

- There is limited information available on the RP's work on hazard combinations, cliff-edge effects and beyond design basis margins within this GDA. I have identified examples, such as for seismic hazards, where there is additional resilience incorporated in the BWRX-300 design, beyond the design basis, which provides confidence in the design. I am satisfied that the RP identified areas for further development on these topics, as part of its FAP (ref. [8]), and that these could be addressed as part of a future Step 3 GDA or future site-specific activities.

- With the currently available information from the safety case, and assurance gained during this two-step GDA, I am content with the development of the fundamental adequacy of the design and safety case in the external hazards area.

166. Overall, based on my assessment, and subject to the provision and assessment of suitable and sufficient supporting evidence in either a future Step 3 GDA or during site specific activities, I have not identified any fundamental safety shortfalls that could prevent ONR permissioning the construction of a power station based on the generic BWRX-300 design.

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Appendix 1 – Relevant SAPs considered during the assessment

SAP reference	SAP title
EHA.1	Identification and characterisation
EHA.19	Screening
EHA.2	Data sources
EHA.3	Design basis events
EHA.4	Frequency of initiating event
EHA.6	Analysis
EHA.18	Beyond design basis events
EHA.7	‘Cliff-edge’ effects
EHA.8	Aircraft crash
EHA.9	Earthquake
EHA.11	Weather conditions
EHA.12	Flooding
ELO.4	Minimisation of the effects of incidents
SC.2	Safety case process outputs

Appendix 2 - Outputs of BWRX-300 External Hazards Identification and Screening

Type of External Hazard	Within scope of GDA	Site-specific but reassurance can be provided during GDA	Bounded by another hazard	Site-specific
Meteorological	Extreme rain, extreme snow, fog, high air temperature, high water temperature, humidity, tornadoes, lightning, low air temperature, low water temperature, strong winds.	Hail, solar storms, salt storm, sandstorm, volcanic activity.	Underwater temperature, meteorite.	Drought, extreme air pressure (high/low/gradient), frost (soil and white), ice cover (surface ice), ice storm/freezing rain/sleet.
Hydrological	N/A	Corrosion, external flooding, frazil ice, high water level, high tide, low water level, seiche, storm surge, waves.	N/A	Coastal erosion, groundwater, ice barriers, other extraordinary waves, river diversion, strong currents (underwater erosion), tsunami, underwater landslide, water surface variation.
Seismic	N/A	Earthquakes.	N/A	N/A

Type of External Hazard	Within scope of GDA	Site-specific but reassurance can be provided during GDA	Bounded by another hazard	Site-specific
Geological	N/A	N/A	N/A	Above-water landslide, avalanche, erosion, excavation work, ground collapse, ground vibration (for example, due to nearby explosions), land rise, landslide, soil shrink-swell.
Biological	N/A	Natural airborne hazards (birds, leaves, ash etc), water borne material plugging water intakes/organic material in water.	N/A	Biological events (microbial corrosion).
Aircraft impact	N/A	Accidental aircraft impact.	N/A	N/A
LOOP	N/A	LOOP.	N/A	N/A
External fires	N/A	External fires.	N/A	N/A

Type of External Hazard	Within scope of GDA	Site-specific but reassurance can be provided during GDA	Bounded by another hazard	Site-specific
Industrial and man-made	N/A	Chemical release after transportation accident, electromagnetic interference, explosion after transportation accident, externally generated missiles and blasts, releases from industrial facilities, adjacent nuclear sites.	Blockage or damage to cooling water intakes, eddy currents into ground, satellite crash.	Chemical release after pipeline accident, chemical release and contamination from chemicals, chemical release outside or inside site, chemical releases into water, collapsed structures/falling objects, contamination from chemicals, explosion after pipeline accident, explosion outside plant, ground contamination (for example, from chemicals), high air pollution, impurities in water from ship release (solids and liquids), man-made explosion (deflagration and detonation), missiles (from military activity or other plant), ship accidents, train crash, vehicle impacts with plant SSCs.

Appendix 3 – Summary of BWRX-300 UK Generic Site Envelope (GSE) Values, with and without climate change adjustment, compared to BWRX-300 Standard Plant Design (SPD) parameters

External Hazard	BWRX-300 UK GSE value (excluding climate change adjustment)[2]	BWRX-300 UK climate change adjustment (to year 2100)	BWRX-300 UK GSE value (including climate change adjustment)	BWRX-300 SPD parameter	Margin between BWRX-300 SPD parameter and BWRX-300 UK GSE value?
High air temperature	40.2 ˚C (coastal) 45.4 ˚C (inland)	+5.4 ˚C	45.6 °C (coastal) 50.8 °C (inland)	Standard Plant maximum dry bulb temperature designed to 39.7 °C. Safety Class 1 SSCs exposed to ambient environment conditions in MCR and SCR designed to 47.2 °C. Safety Class 1 SSCs exposed to ambient environment conditions in Reactor Building and Control Building designed to 37.8 °C.	No – RQ-01853 raised on this (ref. [109]). No durations defined for BWRX-300 SPD parameter or BWRX-300 UK GSE value. See further discussion in section 4.3.3.2.

[2] Durations are included where these are available. Where no duration is stated, this has either not been defined or is not available within this two-step GDA.

External Hazard	BWRX-300 UK GSE value (excluding climate change adjustment)[2]	BWRX-300 UK climate change adjustment (to year 2100)	BWRX-300 UK GSE value (including climate change adjustment)	BWRX-300 SPD parameter	Margin between BWRX-300 SPD parameter and BWRX-300 UK GSE value?
Low air temperature	-22.0 ˚C (coastal) -38.4 ˚C (inland)	Conservatively assumed to be zero	-22.0 ˚C (coastal) -38.4 ˚C (inland)	-40 °C for less than two hours. -32.5 °C for 1 day.	No durations defined for BWRX-300 UK GSE value. The SPD low air temperature value for less than two hours bounds BWRX-300 UK GSE values. Durations would be needed for the BWRX-300 UK GSE low air temperature value to compare with SPD parameters, particularly for longer duration events.
Extreme rain	163 mm in 1 hour 400 mm in 24 hours	+29% for 1 hour value	210.3 mm in 1 hour 400 mm in 24 hours	Plant structures designed to accommodate maximum rainfall rate of 493 mm/h and maximum short-term rain fall rate of 157 mm in 5 minutes.	Yes, even with different return periods and durations.

External Hazard	BWRX-300 UK GSE value (excluding climate change adjustment)[2]	BWRX-300 UK climate change adjustment (to year 2100)	BWRX-300 UK GSE value (including climate change adjustment)	BWRX-300 SPD parameter	Margin between BWRX-300 SPD parameter and BWRX-300 UK GSE value?
Strong winds	43.1 m/s (mean wind velocity)	+2 m/s	45.1 m/s	Severe Wind: 71.5 m/s (160 mph) for return period of 3,000 years. Extreme Wind: 89.4 m/s (200 mph) Severe wind speed for Seismic Category A & B structures is defined as the (straight-line) 3-second gust wind speed based appropriate standards, with suitable corrections for local conditions per NUREG-0800 Section 2.3.1 (ref. [124]). Value of 71.5 m/s (160 mph) is based on American Society of Civil Engineers (ASCE) 7-16 Risk Category IV basic wind speed maps (3-second gust), which corresponds to a Mean Recurrence Interval of 3,000 years.	Yes, even with different return periods and duration not yet defined.

External Hazard	BWRX-300 UK GSE value (excluding climate change adjustment)[2]	BWRX-300 UK climate change adjustment (to year 2100)	BWRX-300 UK GSE value (including climate change adjustment)	BWRX-300 SPD parameter	Margin between BWRX-300 SPD parameter and BWRX-300 UK GSE value?
Tornadoes	Maximum tornado wind speed 89.4 m/s Tornado maximum pressure drop 63 mbar Tornado pressure drop rate 25 mbar/s Tornado missile dimensions, mass and velocity included in Table D-2 in Chapter 15.8 of PSR (ref. [8])	Not assessed	Maximum tornado wind speed 89.4 m/s Tornado maximum pressure drop 63 mbar Tornado pressure drop rate 25 mbar/s Tornado missile dimensions, mass and velocity included in Table D-2 in Chapter 15.8 of PSR (ref. [8])	Maximum wind speed 103 m/s Maximum rotational speed 82 m/s Translational speed 21 m/s Radius 45.7 m Tornado maximum pressure drop 8.3 kPa Tornado pressure drop rate 3.7 kPa/s	Yes, even with different return periods and duration not yet defined.
Extreme snow	1.5 kN/m^2 Snow depths not defined within GSE	To be considered at site specific assessment	1.5 kN/m^2	Maximum ground snow load of 2.5 kN/m^2 for normal winter precipitation events and 5 kN/m^2 for extreme winter precipitation events.	Yes, even with different return periods and durations.

External Hazard	BWRX-300 UK GSE value (excluding climate change adjustment)[2]	BWRX-300 UK climate change adjustment (to year 2100)	BWRX-300 UK GSE value (including climate change adjustment)	BWRX-300 SPD parameter	Margin between BWRX-300 SPD parameter and BWRX-300 UK GSE value?
High humidity	100%	Not assessed as GSE is 100%	100%	SPD values are based on wet bulb temperature exceedance values so are not directly comparable with UK GSE. Maximum high humidity average wet bulb globe temperature index of 30.3 ˚C is defined for SPD for 0% exceedance maximum wet bulb temperature day.	N/A – No SPD value currently available.
High water temperature	30 ˚C	+2.2 ˚C	32.2 ˚C	Not available within GDA as heat sink design is site-specific and out of scope for GDA Step 2.	N/A – No SPD value currently available.
Low water temperature	-1.9 ˚C	Not required	-1.9 ˚C	Not available within GDA as heat sink design is site-specific and out of scope for GDA Step 2.	N/A – No SPD value currently available.

External Hazard	BWRX-300 UK GSE value (excluding climate change adjustment)[2]	BWRX-300 UK climate change adjustment (to year 2100)	BWRX-300 UK GSE value (including climate change adjustment)	BWRX-300 SPD parameter	Margin between BWRX-300 SPD parameter and BWRX-300 UK GSE value?
Lightning	Lightning flash density – 1.4 flashes/km^2/year Lightning strike current 300 kA Average days of thunder – 15 days/year	Frequency projected to increase in summer and spring. To be considered during site-specific assessment.	Lightning flash density – 1.4 flashes/km^2/year Lightning strike current 300 kA Average days of thunder – 15 days/year	Not available. Lightning and grounding protection systems described in Chapters 8 and 15.8 of PSR (refs. [8], [23]).	N/A – No SPD value currently available.
Earthquake	Design Basis Earthquake (DBE) – 0.3g OBE not defined within GDA GSE and will be defined during site-specific stage.	Not applicable	Design Basis Earthquake (DBE) – 0.3g	Horizontal Generic Design Response Spectra (GDRS) are anchored at 0.3g PGA. Vertical GDRS are developed by multiplying horizontal GDRS by a frequency-dependent vertical-to-horizontal (V/H) spectral ratio (ref. [8]).	GSE value and SPD value are the same.

Appendix 4 – UK ABWR GDA external hazards assessment findings

Assessment Finding Number	Assessment Finding	Considered in BWRX-300 GDA?
AF-ABWR-EH-01	As a result of the assumptions made in the GSE for GDA, a future licensee shall perform a site-specific assessment to determine the design basis tornado wind speed. Depending on the results of the assessment, the implications of the maximum wind speed of a T2 tornado should be compared with the design withstand to demonstrate that the impact is acceptable with adequate margins.	The RP has defined a maximum tornado wind speed, tornado maximum pressure drop, tornado pressure drop rate and tornado missile dimensions, mass and velocity included within the BWRX-300 UK GSE. See Section 4.3.4 and Appendix 3 of this assessment report for more information. Further analysis will be undertaken and captured in a future version of the safety case. Future work is tracked under FAP items PSR 15.8-135, 15.8-142, 15.8-143, 15.8-144 and 15.8-146 (ref. [8]).
AF-ABWR-EH-02	Due to the requirement for detailed design information, and due to developments in methods of assessment, a future licensee shall consider sources of naturally-occurring electromagnetic interference from extreme space weather events including geomagnetic storms, solar radiation storms, and radio blackouts. This shall include an assessment of hazard magnitudes, frequencies, and potential effects, along with reasonably practicable resilience enhancements to protect against these hazards to reduce risks ALARP.	Electromagnetic interference and space weather are both considered as site-specific hazards for GDA, with some reassurance provided during GDA (ref. [8]). Detailed analysis has not been undertaken at this stage for either hazard, and no BWRX-300 UK GSE value has been defined. The RP's response to RQ-01832 (ref. [120]) highlights specific BWRX-300 design features that may reduce risks from Geomagnetically Induced Currents (GIC).

Assessment Finding Number	Assessment Finding	Considered in BWRX-300 GDA?
		Future work is tracked under FAP items PSR 15.8-143, 15.8-144 and 15.8-146 (ref. [8]).
AF-ABWR-EH-03	As a result of the assumptions made in GDA, a future licensee shall review the combinations of hazards at the site-specific stage to ensure that all reasonably foreseeable combinations of hazards for a specific site have been included in the analysis.	The RP submitted a topic report for combined hazards (ref. [86]), which provides a description of the combined hazards identification and assessment process for the BWRX-300. The RP has not identified any hazard combinations within this report, as this was out of the RP's scope for this GDA (ref. [49]). The RP's topic report for combined hazards (ref. [86]) identifies that further work is required for both individual hazards and combined hazards. This is identified in FAPs PSR 15.7-72 and 15.8-135 to be addressed in a future version of the safety case, after Step 2 of GDA.
AF-ABWR-EH-04	As a result of the assumptions made in GDA, a future licensee shall consider and implement adequate water sealing and/or elevation of the Heat Exchanger Building and transformer, Reactor Building, Control Building, Electrical Diesel Generator Buildings, and Backup Building. The determination of requirements shall be based on site-specific evaluation of external flooding beyond the design basis in accordance with the principles of ALARP.	This has not been considered within the BWRX-300 GDA and may not be fully applicable to the BWRX-300 design.

Assessment Finding Number	Assessment Finding	Considered in BWRX-300 GDA?
AF-ABWR-EH-05	As a result of assumptions made concerning Beyond Design Basis hazards in GDA, a future licensee shall consider whether or not the site-specific seismic analysis demonstrates that the generic site envelope's seismic hazard definitions are bounding. If the generic site envelope's seismic hazards are not bounding, a future licensee shall assess the vulnerabilities of the UK ABWR to beyond design basis hazards assumed in the generic design to be bounded by generic site envelope seismic hazard definitions.	This has not been considered within the BWRX-300 GDA. Future work is tracked under FAP items PSR 15.8-137, 15.8-142, 15.8-143 and 15.8-144 (ref. [8]).